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HARRIMAN ALASKA SERIES

VOLUME XIV

Monograph of the Shallow-water Starfishes of the North Pacific Coast from the Arctic Ocean to California

(WITH 110 PLATES)

BY

ADDISON EMERY VERRILL

Professor Emeritus of Yale University

PART 1. TEXT

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EDITOR'S PREFACE.

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The Starfishes collected by the Harriman Alaska Expedition were sent to Professor A. E. Verrill for study and report; and through the courtesy of various museums of the United States and Canada numerous additional specimens from the West Coast were placed in his hands. With this rich material at his disposal, Professor Verrill undertook a monographic revision of the Starfishes inhabiting the shallow waters of the Pacific from Arctic Alaska south to California.

In the course of three or four years (by 1904) the larger part of the monograph had been written, most of the species (including Stimpson's types, in the United States National Museum) had been photographed, and more than 40 plates had been reproduced and printed. But pressure of other duties so delayed the completion of the work that a dozen years have elapsed since it was begun. The long delay, however, has not been without compensations, for much new material has come to Professor Verrill's hands, including collections from Patagonia and Fuegia, enabling him to add matter of great importance on the geographic distribution of the group.

In the meantime, Mr. E. H. Harriman, organizer and patron of the Expedition, having passed away, the publication of the work, with its large series of plates, has been generously provided for by Mrs. Harriman.

In view of Professor Verrill's lifelong studies of the Starfishes, it is believed that the present monograph will long remain a standard authority on the subject, and that it will receive a hearty welcome from all workers on the Echinoderms.

C. HART MERRIAM,
Editor.

WASHINGTON, D. C.,
May, 1913.

M886283

SHALLOW-WATER STARFISHES OF THE NORTH PACIFIC COAST FROM THE ARCTIC OCEAN TO CALIFORNIA

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PREFACE.

THIS report was originally planned to include only the littoral and shallow-water species of the starfishes of Alaska and adjacent waters contained in the fine collections made on the Harriman Expedition by Dr. (now Professor) W. R. Coe, together with the collections in the Yale Museum, previously received from the same region, including a number of my original types. The subsequent reception of numerous other large collections from the same and adjacent regions soon led to a great extension of the work, so as to include all the shallow-water species from California to Bering Sea. The various collections sent to me by the Canadian Geological Survey through the late Mr. J. F. Whiteaves, and later through Professor John Macoun have been particularly large and valuable, containing many new forms. My thanks are especially due to Professor Macoun and other members of the Canadian Survey for these favors.

A small but very important collection was sent to me from the Museum of Comparative Zoölogy, through the kindness of the Director, Mr. Samuel Henshaw, and of Dr. H. L. Clark; I also enjoyed an opportunity to study there the entire collection of starfishes from the Northwest coast.

A large collection was also received, through Dr. C. F. Newcombe, from the Provincial Museum of British Columbia at Victoria. Professor Trevor Kincaid, University of Washington, Seattle; Professor W. E. Ritter, University of California, Berkeley, and others have also sent useful collections; and to all these I wish to express my obligations for assistance given.

A small collection, mostly from Bering Sea, was sent to me by the U. S. National Museum, and was very useful for the more Arctic species. I am also indebted to the National Museum, through the kindness of Dr. R. Rathbun and Miss M. J. Rathbun, for photographs of the type specimens of the several species early described by Dr. Wm. Stimpson, which have been of great use and are now reproduced on my plates. Several of these have not been previously figured.

The report was very nearly finished, mostly in its present form, previous to 1904, and forty-three plates had been engraved and printed at that time.

In the meantime, Prof. W. K. Fisher, of Stanford University, has published (1911 *b*) an extensive work on some of the orders of starfishes of the North Pacific, including not only very many deep-water species, but also considerable numbers from the shallow waters of the same regions, covered by my report, and including many of the species previously described and figured by me, in this work.

He had the advantage of having studied my specimens, manuscripts and plates several years ago, while visiting me at the Yale Museum. Yet in some cases our conclusions are somewhat divergent.

I have not seen his types, nor have I been able to devote so much time as I would like to the correlation of his species of certain difficult genera, like *Solaster* and *Henricia,* with my own. But I trust that the figures and descriptions given in both works will enable future students to understand what the forms discussed really are, regardless of the names.

For the numerous excellent drawings of miscroscopic details and for nearly all the photographs, I am indebted to the careful work of my son, Mr. A. Hyatt Verrill, who has devoted much time to the work during several years.

ADDISON EMERY VERRILL.

NEW HAVEN, CONN., July, 1912.

Monograph of the Shallow-water Starfishes of the North Pacific Coast from the Arctic Ocean to California, with Revisions of Various Extra-limital Genera and Species.

BY

ADDISON EMERY VERRILL,
Professor Emeritus of Yale University.

INTRODUCTION.

RICHNESS OF THE STARFISH FAUNA; CAUSES.

THE Northwestern Coast of North America seems to be the headquarters or metropolis of shallow-water starfishes. No other region, so far as known, has anything near so many species, nor so many generic and family types, in shallow water, nor so great an abundance of individuals.

The species and genera confined to the deeper waters off these shores seem to be equally numerous, or more so.

At present there are over one hundred shallow-water species known from that region, besides about twenty named varieties.

The abundance and variety of starfishes in these shallow waters is apparently greater than at Panama, the West Indies, or the most favorable parts of the East Indies in similar depths.

This profusion of starfishes does not hold good for the other classes of Echinoderms. The Sea-urchins (Echinoidea) are represented by comparatively few species, of which only about five are common, and those belong to widely distributed genera. But this is about the normal number for any similar cold-water fauna.

The serpent stars (Ophiuroidea) are represented by about the usual number of species, none of them of unusual types.

The Crinoidea are represented in shallow water only by a single large, comatulid species, so far as known to me.

The Holothurians are numerous, but not remarkably so, and mostly of common genera.

This coast seems admirably adapted for the permanent occupation and evolution of starfishes, and similarly for certain groups of other marine invertebrates and fishes.

Among the fishes the Salmonidæ may be mentioned. Among the mollusca some groups, like the limpets, chitons, Buccinidæ, and other families, are much more abundant than in any other regions.

Nemerteans and tubicolous Annelids are also remarkably large and numerous.

There is every reason for thinking that such groups, including various genera and families of starfishes, have lived and flourished on that coast for many geologic periods, and have developed in that region, by continuous evolution, most of the species found there at present, as well as great numbers that have disappeared.

Indeed, I am led to conclude that this region has been, for long ages, a center of evolution, from which various generic and specific types of starfishes have been dispersed to other faunal areas, with or without subsequent changes.

It is not at all improbable that some arctic and boreal species of the North Atlantic originated on the Alaskan coast and have since crossed to the Atlantic by way of the Arctic Ocean, when the arctic climate was warmer.

Others may have migrated southward to the subtropical and tropical regions of Mexico and Central America, and even to the Antarctic Seas, for some of the deep-water Patagonian and antarctic species show peculiar affinities with the Alaskan species.

Such migrations, across the tropics, would easily be possible for species having a considerable range in depth, for their congenial temperatures could easily be found at no great depth, even off Panama.

One reason for the great variety and persistence of the starfishes and other groups on this coast is, no doubt, the fact that the temperatures of the waters were not seriously reduced during the Glacial Period, while those of the North Atlantic were rendered so cold that the preëxisting fauna was largely exterminated, while the survivors were driven southward, except in the case of eminently arctic and deep-sea species.

Another very favorable condition is the comparatively equable temperature of those waters, due to the reflex of the great Japanese tropical current of water. Its influence in modifying the climate of the whole coast, south of the Aleutian Islands, at least, is well known.

For the prosperity of most marine animals, equability of temperature is exceedingly favorable, whether high or low, especially at the breeding season.

No doubt the comparative uniformity of the temperatures at all seasons, and over vast areas, in the deep sea, is the principal cause of the great abundance of starfishes and many other groups of animals in the deep sea and of their wide distribution.

Constancy of temperature at the breeding season, year after year, is of the greatest importance to nearly all animals, both in the sea and out of it, as the writer pointed out many years ago in the case of birds,[1] and as has since been confirmed by other investigators for birds and other groups.

Another very favorable condition, for the multiplication of starfishes on this coast, is the vast extent and broken condition and rocky character of the coast-line, with innumerable islands, bays, straits, fiords, and inlets, affording every variety of stations and any amount of shelter from severe storms, and at the same time furnishing innumerable suitable stations on the rocky shores, for the growth and increase of all sorts of plant and animal life, on which the starfishes may feed. It has been stated that the coast-line of Alaska and the adjacent islands exceeds 26,000 miles, or more than the circumference of the earth. That of British Columbia is also of vast extent.

FOOD AND FEEDING HABITS OF THE STARFISHES.

The littoral and shallow-water starfishes are nearly all carnivorous, by preference, and feed very largely on the barnacles and mollusca that live among, or attached to, the rocks, such as mussels, oysters, limpets, chitons, small spiral gastropods, etc.

Considering the great numbers and large sizes of many of the starfishes, the wonder is that they have not already entirely exterminated those mollusca on which they largely feed.

The vast amount of damage done to the cultivated oyster beds on our Atlantic coast by a single small species of starfish (*Asterias forbesi*) is well known. What then must be the destruction wrought to the bivalves on the Pacific coast, where there are some forty related species, with similar habits, many of them becoming over two feet across?

One of our native starfishes, six inches across, will eat over twenty small oysters in one day. Probably it would take a hundred oysters or mussels to satisfy one of the giant starfishes of Alaska or Puget Sound.

[1] Proceedings Boston Soc. Nat. Hist., vol. x, p. 259, 1866.

The great abundance, size, and voracity of these Pacific starfishes will always be a great hindrance to the cultivation of oysters, mussels, etc., on that coast, except, perhaps, where the water is distinctly too brackish for starfish life.

Fortunately for the mollusca, at least, most of the larger littoral starfishes are more or less cannibals. When opportunity occurs, they do not hesitate to devour each other.

From the stomach of a large ten-armed *Solaster,* I have taken the half-digested ray of an *Asterias* that must have been a foot across when living. An inch or two of the ray still protruded from the mouth of the *Solaster,* for it was much too large to swallow entire.

The various kinds of starfishes that inhabit rocky shores, clinging to the rocks, have large numbers of strong, muscular sucker-feet, each tipped with a perfect sucker for adhesion. In the ordinary five-rayed kinds, six to eight inches across, there will be four close rows of such suckers the whole length of the ray, perhaps 200 to a ray; or 1,000 on the five rays.

In the case of the many larger five-rayed and six-rayed kinds, two feet across, the number of suckers may be 4,000 to 8,000 or more.

How many there are on the big twenty-rayed or twenty-four-rayed star of that coast, which becomes over thirty inches across, and has the suckers mostly crowded into four rows, on each ray, nobody knows, for apparently nobody has had the patience to count them. Probably there may be more than 40,000. I refer to the great *Pycnopodia* or "sun-star." (See pl. XXIX.)

Such starfishes are able to open an oyster or mussel by a long and steady pull with these suckers, while the rays are wrapped around the victim. All such starfishes can evert the large, loose, bag-like stomach and wrap it around its prey till digestion is completed, if it be too large to swallow entire. But the mouth is also very extensible and dilatable, so that they can swallow objects surprisingly large. I have often taken sea-urchins an inch or more in diameter with the spines nearly all in place, from the stomachs of starfishes of no more than ordinary size.

ACTIVITIES OF STARFISHES; MIGRATIONS; RATE OF TRAVEL.

Although most starfishes, as ordinarily seen in life clinging to stones, etc., appear very sluggish and slow in their motions, they are really able to travel to considerable distances and undoubtedly, in some cases, make migrations of considerable extent, either in

search of food or to seek more congenial temperatures in deeper or shallower water, or for other reasons, such as breeding habits.

In Long Island Sound it is a common experience of the oyster cultivators to find that many thousands of starfishes (*Asterias forbesi*) suddenly appear on certain oyster grounds which had been nearly or quite free of them a few days previously. If undisturbed for a few weeks they may destroy thousands of bushels of oysters and then as suddenly disappear from the devastated grounds, to visit some other locality.

In the autumn, September to November, as I have myself observed, year after year, at Outer Island, of the Thimble Islands group, in Long Island Sound, they migrate upward from deeper to shallower water, and may then be found in myriads on rocky shores between tides, where none were to be seen a few days before.

At such times large numbers are often caught and destroyed in the interests of the owners of oyster grounds in the vicinity. In some seasons a boy, one of my grandsons, often caught during low tide two or three bushels, morning after morning, on one small island, up to a total of fifteen or sixteen bushels, and more still came up every morning. These were mostly not more than half-grown and a bushel would usually count up to 1,000 or more. The same operation was carried on at many adjacent islands by others, with similar results. The effect of this wholesale slaughter was said to have notably decreased the loss of oysters on the oyster grounds of the district during the next year.[1]

At this time the starfishes were feeding mainly on the young oysters of the season, which had "set" thickly on all the rocks and ledges, below half-tide, but they were also, in many cases, feeding on the rock barnacles (*Balanus balanoides*), which were also abundant on the rocks.

Later in the season they disappear, going into deeper water to avoid freezing temperatures.

I have repeatedly tested their rate of travel, on the shores of Outer Island. By placing a hundred or more in a small pool of water left by the tide at about half-tide mark, it was easy to ascertain how far and in what directions they would travel during

[1] Immense numbers of this same starfish are also taken in Long Island Sound and other oyster-growing waters by dragging "tangles" or "swabs" over the oyster beds, as first recommended by the writer in 1873 and 1876. A single oyster steamer by this means has often taken twenty-five barrels or more in a short time.

about six hours, while the tide was above the outlet of the pool, which was on a nearly smooth, gently sloping, granite ledge.

In brief, nearly all left the pool, and travelled downward, but in irregularly divergent lines, to various distances, varying from one to about fifteen feet. The majority followed a nearly straight course down the more sloping parts of the ledge, but were readily diverted to one side or the other by small variations in the slope. Those that travelled the greater distances probably left the pool soonest, and were perhaps in more active condition. Selecting a dozen or so of the best travellers, they might average ten feet to twelve feet in six hours, or nearly two feet an hour, providing they left the pool about as soon as it was covered by the tide, which was probably true of some of them, at least. As their motions are rather deliberate and continuous, they could, no doubt, keep up this rate for many hours, or about 336 feet in a week.

Yet these were mostly rather small, from 4 to 6 inches across, and the larger ones were found to travel much faster than the young ones, for they have a much larger number of sucker-feet, which are also stronger and longer.

Such observations as the above give, of course, only an approximate idea of their rate of travel. These were neither impelled by hunger nor by cold, but merely by an instinctive tendency to seek a lower level. A stronger stimulus might have increased the speed.

Very large starfishes, like many of the west coast species, would probably travel very much faster, and perhaps those with many rays and a vast number of suckers, like *Pycnopodia* and *Solaster,* would be still more speedy. By actual count a half-grown *Pycnopodia* was found by the writer to have over 22,000 ambulacral feet.

At any rate, the observed speed would be quite sufficient to permit them to ascend or descend a sloping sea bottom quickly enough to avoid any ordinary changes in the temperature of the water liable to be injurious, and also sufficient to enable them to seek their ordinary food on new grounds. It is known that, in spite of their voracity, they can go for many days, or even weeks, without any food and still remain active and in good health.

However, there are other families of starfishes that are far more lively, while some others are far more sluggish.

The most lively starfishes known to me belong to the genus *Luidia.* Some of these are very large species.

These live on bottoms of fine sand or mud, more commonly in rather deep water, but often close to the shore in sheltered, shallow,

sandy bays and harbors. Some of the species have more than six rays. In all cases the rays are long, flattened, and very flexible. Ordinarily when at rest they lie just beneath the surface of the sand, which soon forms into star-like impressions, agreeing with the starfish in size and form. This is due to the minute currents of water produced by the ciliary motions connected with the respiration of the starfish by means of the dorsal papulæ.

When disturbed, the starfish glides away quickly, just under the loose superficial sand, using its "sucker-feet" or "ambulacral feet" as paddles for swimming or gliding. These ambulacral feet are much larger and longer than usual and are much flattened transversely, and have no terminal sucker, but end in a point. They are very muscular and can be waved back and forth, like paddles, in unison, so that the motion is more like rowing or swimming than running or creeping. While under the sand, no doubt the pressure against the sand causes them to act something like legs or feet; but when placed in an aquarium without sand, they can swim or glide along the bottom and up the perpendicular sides with surprising rapidity.

My own observations on this genus were made in 1901, at Bermuda[1] on *Luidia clathrata* Say, a five-rayed species.

Similar observations have since then been made by others on different species of *Luidia,* so that this mode of locomotion is probably common to all the species of the genus.

LARVAL STAGES; PROTECTION OF EGGS AND YOUNG; INCUBATION.

The wide and rapid distribution of many, if not most, starfishes of shallow seas is, however, due to the fact that nearly all produce vast numbers of minute eggs, which develop into small, singular, bilateral, free-swimming larval forms (bipinnaria, brachiolaria) that require many days or weeks to go through their metamorphoses before settling down to the bottom in the starfish form. While in these larval stages, they may be drifted long distances by waves and currents and finally settle down in places far from their place of origin. Of course, in most cases they become widely dispersed and vast numbers perish, but sometimes, on the other hand, myriads of young may happen to drift along in company, by the action of a current, and so finally locate as a vast colony in a new home.

[1] A. E. Verrill, 1901, p. 36, and Zoölogy of Bermuda, Article 10, p. 36, 1903. (See Bibliography.)

Perhaps the sudden appearance of great numbers of young starfishes on certain oyster grounds, where they were not found previously, may be accounted for in this way. When well fed on young oysters, these little baby starfishes grow rapidly and soon become large enough to attract attention and do great mischief, even in one season.[1]

Certain genera and species of shallow-water starfishes, and perhaps a large proportion of the deep-sea species, do not produce so many minute eggs, nor do these develop into free-swimming larvæ. On the contrary, the mother retains the eggs and cares for them till they pass through an abbreviated metamorphosis and develop into minute young starfishes provided with "sucker-feet" or *podia* to enable them to take care of themselves.

Commonly, in such cases, the eggs and young are held under and around the mouth in large clusters. During the time required for their development the mother appears to be incapable of taking any food, owing to the obstruction of the oral region. The young are often attached by a larval actinal pedicel in clusters or strings.

This is the mode of carrying the eggs and young observed in several species of *Henricia, Anasterias, Sporasterias,* and *Podasterias,* and in numerous small species of Asteriidæ, belonging to the genus *Leptasterias.* I have personally observed this in *L. compta, L. tenera,* and *L. littoralis* of the New England coast, and in *L. epichlora* and *cribraria* of Alaska. The young of *epichlora* were collected by Dr. W. R. Coe. (See pl. LXXXV, figs. 2, *a-f.*) In all these the genital pores are on the ventral side, near the mouth.

In some other cases (*Leptychaster*) the mother carries the eggs on the back, between the spines.

Another method occurs in the genus *Pteraster,* and probably in all the related genera of the family Pterasteridæ. In these there is a large dorsal "nidamental pouch," marsupium, or better, *gonocodium,* for the retention of the eggs and the development of the young, which remain in it until fully formed and sometimes up to 10 to 15 mm. or more in diameter.

This gonocodium is formed by a tent-like membrane, which is supported and kept stretched by the tips of slender, elongated, radiating spinules, arising from the dorsal ossicles, and long enough

[1] Starfishes that have such minute eggs and young usually have minute genital pores, situated in pairs, dorsally, in the interradial areas. Those that have large eggs that they carry around or over the mouth have the genital pores larger, on the ventral side near the mouth, so far as observed.

to leave a considerable cavity beneath it, in which the genital orifices and respiratory papulæ are situated. This membrane is perforated by small pores for the ingress of water, and normally has a large, valvular, central oscule through which the water escapes. The membrane has muscular fibers for contraction.

The eggs are laid and fertilized in the gonocodium, and when the young are matured they often, or perhaps always, escape by ruptures of the membrane, which later heal up—a sort of natural cæsarian operation.

In this group the eggs are few in number, as usual in all cases where the young are well cared for. Several species of this family occur on the west coast. (See pl. XXXII.)

SENSES; INSTINCTS; MEMORY; ACQUIRED HABITS.

Comparatively little is known, from actual observation, as to the nature or acuteness of the senses in starfishes.

At the tip of each ray, in the apical plate, there is a small and very simple eye, or pigmented eye-spot, often red in color during life. It is at the end of the radial nerve. Probably this kind of an eye is of use only for distinguishing different degrees of light, or possibly the shadow of a nearby moving object.

Close to the eye there is a single odd ambulacral tube, generally considered a tentacle, and supposed to have, at least, the sense of touch. However, all parts of the integument, and especially the papulæ and sucker-feet, are also very sensitive to touch. Therefore it may be that these tentacles have some other sense function more developed than elsewhere, possibly that analogous to smell or taste, for appreciating the purity or salinity of the water. They must have a sense for heat and cold, as this determines their migrations at certain seasons. That they are somewhat sagacious and discriminating in their successful selection of the young oysters for food in spite of the labor and time required to open them, is good evidence that they have some sense analogous to taste, and have sense enough to follow it.

That they can be attracted to an open oyster or other favorite food, from some distance, indicates that they have some sense similar to smell, like that of many mollusca and crustacea that are easily attracted by a dead fish or other odorous food. As they have no proper head or central brain, but only a circle of equal nervous centers, it is clear that they can have no consciousness of right or left, forward or backward. Each ray is practically equal to every

other, yet all the vast number of suckers, sometimes 20,000 or more, and all the rays must act in unison or there could be no progression, nor any procuring of food.

Just how starfishes decide to travel in one direction rather than in another is a problem difficult to solve.[1]

Dr. Jennings, who has experimented extensively with reference to the behavior of starfishes, says very truly that whatever a starfish can do at all it can do in many different ways and seldom does it twice in just the same way. This is particularly applicable to its modes of righting itself when turned over, getting out from under weights, elastic bands, etc. He found that when a starfish had been forced to use the same arms to right itself very many times and for several weeks, it could thus be trained to continue to use the same arms, and thus had acquired a new habit, but if left to itself it lost the habit in about a week.

Perhaps the preference of the starfish to use the same rays was mainly because, by repeated use, the muscles of those rays had become somewhat larger and stronger by the systematic "training."

I know of no other successful attempts to educate a starfish. In nature they seem to show some memory and some persistency. I once placed a large active holothurian (*Thyone briareus*), that I wished to figure, in one end of a large aquarium, about four feet long, while there was a starfish (*Asterias forbesi*) at the other end. Next morning the starfish was mounted on the *Thyone* and had slightly eroded its skin by means of its oral spines. I disengaged the *Asterias,* put it at the opposite end of the tank with stones and other obstacles between, and supplied other food, such as cracked mussels, etc., and other *Thyones,* apparently just as good. In a couple of hours it was back again, working away at the same spot on the holothurian. The same course was taken a second time, with the same result. The starfish was evidently bound to eat that particular *Thyone* or go without any dinner. I had to remove it from the tank to save the *Thyone.* Apparently the *Asterias* either remembered where his chosen dinner rested, or else it had a keen sense of smell to distinguish it from others of the same species, and from other natural food.

In respect to maternal instincts, the most interesting case known to me was told to me by Prof. Louis Agassiz, while I was a student

[1] Dr. L. J. Cole (Journ. Exper. Zoöl., XIV, No. 1, 1913) has recently made some interesting experiments on the behavior of *Asterias forbesi* under special conditions, as to the relative use of the various arms as anterior or directive, etc.

and assistant with him about 1862. I am not aware that it has been published. It is recorded in a diary kept by me at that time.

He said that he had a large aquarium, at Nahant, Mass., in his summer residence, I think, and placed in it a large female *Solaster endeca,*[1] which was carrying a cluster of eggs over the oral area. As an experiment, he removed the cluster and put it at the extreme opposite end of the aquarium. In a few hours the starfish found the cluster and replaced it as at first.

Mr. E. Desor (Proc. Boston Soc. Nat. Hist., vol. III, p. 11, 1848) records a similar observation in the case of *Henricia sanguinolenta.*

I have, personally, never had a chance to repeat this experiment, for though I have dredged thousands of *Solasters,* it has always been at the season of the year when they were not carrying eggs. Such experiments should be repeated at the various permanent seaside laboratories now in existence on both coasts. None existed during the long period of most of my field work, except, after 1881, that of the U. S. Fish Commission.

PECULIARITIES OF THE STARFISH FAUNA OF THE NORTH-WEST COAST OF AMERICA.

The general discussion of the geographical distribution of the genera and species and their relations to those of other regions must be left to a final chapter. There are, however, some very peculiar features of more general interest, to which it seems best to call attention in this place.

The great size of many of the species, some of which are among the largest, if not the very largest species known, has already been mentioned.[2]

The *Pycnopodia,* though perhaps not the heaviest, is probably the largest starfish known. It becomes at least thirty-six inches broad; and according to some collectors may be even four feet across.

[1] As no one else has recorded the carrying of eggs by *Solaster,* and as its genital pores are described as minute and dorsal, I suspect that there was an error on my part in recording the name, or on his part in giving it. Perhaps *Henricia* was meant.

[2] At least nine of the species of *Asterias* and allies become there over two feet in diameter. Among these large species are *Orthasterias columbiana* Ver., *O. forcipulata* Ver., *Ev. troschelii* (St.), var. *rudis* V., *Ev. acanthostoma* V., *Pisaster ochraceus* (Br.), *P. giganteus* (St.), *P. lütkenii* (St.), *P. papulosus* Ver., *Pycnopodia helianthoides* (Br.). *Luidia foliolata* becomes about as large.

MULTIPLICITY OF RAYS; VARIABILITY.

It is a singular fact, for which no satisfactory reason has yet been given, that nearly all Echinoderms, whether living or fossil, are normally five-rayed. This rule prevailed quite as constantly in the remote paleozoic ages as in the present period.

The number of rays was apparently well fixed in the unknown primordial ancestors of the earliest fossil Echinoderms of most classes, for all classes of Echinoderms, except, perhaps, the Holothurians, appeared in the early geologic ages, with most of their more important features much as we find them now.

Among Paleozoic Echinoderms, as among modern ones, certain starfishes departed from the five-rayed type by acquiring additional rays. As in some modern genera, this was apparently done in post-larval life by the interpolation, or budding in, of new rays between the older ones, in some of those species having numerous rays.

At present, this is known to occur only in *Pycnopodia* of the Northwest coast; in *Heliaster,* represented by several species on the tropical and subtropical Pacific coasts, from lower California to Chile; and in *Labidiaster,* from Patagonia. It is probable, also, that it occurs in *Rathbunaster* Fisher, a deep-water Californian species, allied to *Pycnopodia.*

Of *Heliaster,* seven species are known. When adult, the number of rays exceeds twenty and in some species is as high as forty to forty-four.

In all its species new rays are gradually interpolated, rather irregularly, between the older ones, all around the circumference, but not without some order.[1]

The same is true of *Labidiaster,* which has numerous long rays when adult.

In *Pycnopodia,* the number of rays when adult is twenty to twenty-four. It normally starts, when very small, with six equal rays. A new pair of rays then appears, one on each side of one of the primary rays; then another pair appears just back of these, and so on in successive pairs.[2] This would always produce an even number of rays. But variations from this bilateral regularity often appear, producing odd numbers. (See pls. LXXIII and LXXIV.)

[1] See H. L. Clark, Starfishes of the Genus *Heliaster,* Bull. Mus. Comp. Zoöl., vol. LI, pp. 25-76, pls. I-VIII, 1907. In this paper all the species are fully described and their modes of adding new rays are explained.

[2] See plates. See Professor W. E. Ritter and G. R. Crocker (Proc. Washington Acad. Sci., vol. II, pp. 247-274, 1900), who give a good account of the process.

All the known species of these three remarkable genera are from the Pacific coast of America and the outlying islands.[1]

Their resemblance to certain fossil starfishes of the Devonian is very striking, and may indicate a continuous descent from those ancient forms. If so, it would be good proof of the antiquity of the West Coast forms, as mentioned above.

Aside from these remarkable and localized genera, there are other genera of the fauna that have numerous rays. The genus *Solaster* is represented there by five or six shallow-water species, and *Crossaster* by one. All these are multiple-rayed, the rays varying from eight to fifteen. In these genera, there is no evidence of the interpolation of new rays in post-larval life. They are also genera that are widely distributed in all seas. (See pls. VIII and X.)

They appear to be more numerous on the Northwest Coast than elsewhere, both as to individuals and species. Several additional species occur in deeper water off the coast. The group may have originated in the North Pacific, in former geologic ages.

The genus *Pteraster* in all other seas has five rays, except *P. obscurus,* of the North Atlantic and Arctic, which ordinarily has six or seven. Variety *octaster* V., of Bering Sea, normally has eight rays, but sometimes seven. Mr. Fisher thinks that it is only a variety of *P. obscurus,* but even if so, it is singular that the latter should be six-rayed in the Atlantic and anywhere from six-rayed to eight-rayed in the North Pacific.

So, likewise, other genera that are generally five-rayed in all other parts of the world are apt to have six-rayed species on the North Pacific coast. This is true of the genus *Asterias* and its subdivisions, in which we find many six-rayed species on that coast, as well as numerous five-rayed ones. Some of those that are ordinarily five-rayed are also often found with six or seven rays. This occurs in other regions, but not so frequently as there.

Among the species of Asteriidæ having normally six or more rays, the following may be mentioned: *Pisaster grandis* (St.), a very large species; *Orthasterias merriami* V.; *A. acervata* St.; *A. kathe-rinæ* Gray; *A. multiclava* V.; *Stenasterias macropora* V.; *Leptas-terias hexactis* (St.); *L. vancouveri* (Per.); *L. æqualis* (St.); *L. coei* V.; *L. epichlora* (Br.), subsp. *alaskensis* V., and several varie-ties of the same species; and *L. macouni* V.

Some of these have occurred with seven rays, and some with five, as abnormal variations.

[1] Two species of *Heliaster* occur at the Galapagos Islands, and one at Juan Fernandez. These were evidently derived from Pacific coast ancestors.

The following species, which are normally five-rayed, have been found with six rays:

Henricia leviuscula (St.), from Alaska.
Henricia sanguinolenta (Müll.), Bering Sea.
Pisaster ochraceus (Br.), Monterey, Calif., and British Columbia.
Patiria miniata (Br.). Six-rayed common; four-rayed and seven-rayed rare; California.
Dermasterias imbricata (Gr.), Sitka.

When we consider the great geological antiquity and remarkable persistence of the five-rayed condition in echinoderms generally, it is very remarkable that so many genera and species of existing starfishes should have acquired the peculiarity of having higher numbers. It seems natural to conclude that there must be some special advantage gained by this increase in rays, which does not obtain in the other classes to the same extent.

At the present time all known species of sea-urchins and holothurians are normally five-rayed, and the same holds good through all the geologic ages for the former class at least. Abnormal sea-urchins with four and with six rays have been observed in a number of species. Dr. Robert T. Jackson, in his recent extensive work,[1] has discussed this and various other variations of sea-urchins very fully. He states that he has personally studied seventy-one cases of more or less complete variations from the perfect five-rayed condition. To find these required the special examination of 50,000 specimens, including many species.

In some species about one individual in a thousand shows variations of this kind.[2]

The serpent-stars (Ophiuroidea) show more variation in the number of rays than the sea-urchins do. Several genera contain some species that are normally six-rayed. The common *Ophiocoma pumila* of Bermuda and the West Indies has about equal numbers of five-rayed and six-rayed individuals living together. Many of the species of *Ophiactis* have six to eight rays while young, and divide autotomously, but when mature they are usually either regularly five-rayed or six-rayed. Yet some of the species of the same genus are always five-rayed and do not divide; so it does not seem to be a matter of great importance in this genus.

[1] Phylogeny of the Echini, Mem. Boston Soc. Nat. Hist., vol. x, 1912. Variations from the pentamerous system are described on pp. 35-50.

[2] See also A. E. Verrill, Amer. Naturalist, vol. xliii, p. 545, for a discussion of the subject with figures.

Variations from the five-rayed condition occur not very rarely among living Crinoids, and were not uncommon among the ancient fossil pentremites and cystideans;[1] but on the whole the crinoids have been pretty constantly five-rayed through all the geologic ages.

We must conclude that all these variations originated at first as "sports," which have persisted by heredity and natural selection, because they were advantageous. It is easy to conjecture that, in the case of two starfishes, otherwise similar in size and structure, living together on a rocky shore and exposed to violent surf, the one with six rays would be able to cling more securely to the rocks than the one with five rays. Therefore, because of the increased number of ambulacral sucker-feet, it might well be the form preserved by natural selection, unless for some other important but unknown reason, the five-rayed condition has certain other more important advantages.

It is certainly true that most of the shallow-water species with multiple rays live among rocks in situations exposed to the surf. This is true of the seven species of *Heliaster,* with very numerous rays; and of *Pycnopodia* with twenty to twenty-four rays, and of the various shallow-water and littoral species of *Solaster* and *Crossaster,* which usually have nine to fifteen rays (rarely eight or less). It is also true of the numerous six-rayed species of *Asterias, Pisaster* and allied genera.[2]

However, the ability to cling tenaciously to rocks may be perfected in other ways, involving equally an increased number of sucker-feet. This is often attained by lengthening the rays, as in many species of *Asterias;* by crowding the suckers into more than four rows, as in some large species of *Pisaster;* and by increasing the size and strength of the suckers.

Although it seems probable that the added protection gained against the violence of the waves by the evolution of more numerous rays and suckers is a real cause for the retention of this feature, it may not be the principal one. The attainment of four rows of sucker-

[1] Some of the paleozoic Cystidea were tri-radial. Hence it has been thought by some writers that this was the more primitive condition and that the pentamerous condition was acquired by the addition of another pair of rays. See Bather, op. cit., 1901.

[2] The family Brisingidæ, however, is mostly confined to deep water. All the species are multirayed, with long rays. Some of them climb over gorgonians, as do many ophiuroids. The genus *Labidiaster,* of the Patagonian region, is found in shallow water among rocks and sea-weeds. It has numerous long rays.

feet in Asteriidæ, as compared with the more primitive two-rowed condition, was probably due to the same causes.

I am inclined to believe that the increase of rays has been due more to the advantage gained in holding their food securely, and in opening bivalves, than for holding to the rocks, though both go together. The starfishes are the most predaceous of the echinoderms. They feed largely on bivalve shells that cling firmly to the rocks, like the oysters, and on others that must be pulled open by means of their numerous muscular suckers, part of which must be used for keeping in a suitable position and part for the opening of the oyster, at the same time, so that the more arms and suckers they have, the more rapidly and effectively they can secure their food, in case they are feeding on large bivalves.

We must admit that, so far as known, the five-rayed and six-rayed individuals of a species appear to be equally well nourished and grow to equal size. Also that the normally six-rayed species of *Asterias* are commonly no larger, nor more robust, than the allied five-rayed species, in the same environment. Even the four-rayed individuals appear to be well nourished and of ordinary size. It is quite possible, however, that they grow more slowly. It is known that the rate of growth of starfishes is very rapid when food is abundant, but very slow when food is scarce. No observations have been made on the comparative rate of growth of six-rayed specimens.

It must be remembered that the variation in the number of rays is necessarily attended by extensive changes in the number, size, and form of the skeletal plates of the body; also in the number of ambulacral feet and water tubes, nerve ganglions, nerve cords, stomach lobes, hepatic glands, and all other internal organs.[1] A six-rayed specimen has twelve reproductive glands, instead of the ten in its five-rayed competitor. If the number of ovules be proportionately large, it would produce twenty per cent more young.

So, likewise, it would have an additional stomach lobe and two more hepatic glands. This would perhaps be of advantage in the

[1] This does not hold good in the cases of the multirayed species of *Heliaster*, according to Clark. (The Genus Heliaster, 1907.) This genus has but five stomach lobes and five pairs of gastric retractor muscles, whatever may be the number of rays. Yet the added rays contribute to digestion in that group, for each ray has a pair of hepatic glands and a pair of gonads.

The term "hepatic gland" must not be understood as implying that these glands correspond precisely with the liver of vertebrates, for it is known that the digestive fluids of echinoderms are different chemically from those of the latter. Some claim that these glands of starfishes are more like the pancreas in function.

digestion of food and cause more rapid growth and earlier maturity, if not greater reproductive powers.

It would be a very interesting experiment to try breeding six-rayed or seven-rayed varieties of some common five-rayed species.

I have found five-rayed young (about 5 per cent) among those carried by a six-rayed mother, in the case of *Leptasterias epichlora*. Fisher states that he has found seven-rayed young in the gonocodium of an eight-rayed *Pteraster obscurus*, and one with nine rays. That six-rayed and seven-rayed varieties might be easily obtained by selection and isolation is very probable. I have observed that in the case of our common New England starfish (*Asterias forbesi*) six-rayed and seven-rayed individuals are much more common in some localities than elsewhere, indicating, perhaps, a tendency to the inheritance of these features.

SPECIES, SUBSPECIES, AND VARIETIES.

Within the limits of recognized species, certain groups of individuals, apparently having a definite distribution and more or less permanency of characters, are regarded as bathymetrical or geographic races. Such races are here called *subspecies*.

In certain genera, for example *Asterias, Henricia, Solaster,* specimens occur which cannot be referred definitely to any species or subspecies. Some of these appear to be local variations, due to unfavorable environments; "sports," "freaks," or "hybrids;" others may be abnormal individuals. They are here called *varieties*. If in future the characters of any of these varieties prove fairly constant, it may become necessary to elevate them to subspecific or even specific rank. To determine the status of these forms, much larger series of specimens than are at present available will be necessary.

It is not unreasonable to think that some of these "varieties" and "subspecies" are incipient species, now in the process of evolution, and that eventually some may become fixed species, while others will disappear by the elimination of the most unfit.

The Northwest Coast appears to be one vast nursery for the origination and evolution of new varieties, subspecies and species of starfishes and various other groups of marine animals.

A peculiar difficulty in the determination of genera and species of starfishes consists in the fact that many, especially of the Asteriidæ, do not attain their adult characters until of considerable size, so that young, or even half-grown specimens, may appear to belong to a different species, or even a different genus, for the more complex

species pass through stages corresponding to the adult condition of simpler or more primitive genera, and there is often no way to tell whether a small specimen is mature or not, without comparison with a series.

HYBRIDISM OF ASSOCIATED SPECIES.

Owing to the fact that numerous related species of several genera are living together on the Northwest Coast, it is natural to conclude that some of them may frequently hybridize, especially if their breeding seasons are coincident. I have seen many hybrids between *Asterias vulgaris* and *A. forbesi* of the New England coast.

There is considerable evidence that this often occurs on the Pacific Coast, leading to the existence of many very puzzling specimens in some groups.

I have personally seen a number of apparent hybrids between diverse species of *Asterias, Pisaster, Henricia,* and other genera abundant on that coast. Perhaps some of the equally puzzling specimens of *Solaster* may also be hybrids.

To determine this matter satisfactorily requires large collections, and especially observations made on the living specimens in their natural environment. The littoral species of *Leptasterias* that carry their young, abundant on the shores, are eminently adapted for such studies, and are easily raised.

This can best be done at one of the seaside biological stations, and for that reason I do not propose to discuss the matter at length in this place. Dr. Fisher, also, has found numerous varieties and connecting forms, some of which he thinks may be hybrids, among the large numbers of specimens of *Henricia* that he has studied.

It is quite probable that some of the now well established species of starfishes of that coast originated at first as hybrids and that others are now in the process of differentiation into varieties and species.

FAUNAL RELATIONS AND DISTRIBUTION OF THE SPECIES.

Details of the distribution of the species must be left to the end of this report, but there are some interesting facts that may well be mentioned here.

The shallow-water starfish fauna of the Northwest Coast, taken collectively, may be considered as consisting of three parts.

1st. Those of more southern or tropical origin that have migrated northward to California or beyond.

2d. Those that are of Arctic or circumpolar distribution and extend southward into Bering Sea, and in many cases to the Aleutian Islands, or much farther south, especially in the deeper waters. Their origin may have been in the North Pacific originally, in many cases.

3d. Those that appear to have originated in the region extending from the Aleutian Islands to California.

The last group is by far the larger and more important. Very likely it is possible to divide that very extensive coast line into two or more faunal districts, but for the starfishes this does not seem to be necessary for the present, for many species range throughout that whole extent of coast.

The limits of distribution on that coast seem to be determined entirely by the temperature of the water, especially in the breeding season, due probably to the greater sensitiveness of the free-swimming larval forms. The adults can regulate their temperatures by migrating into deeper or shallower water as occasions require.

Among the more southern forms are *Orthasterias forreri, Pisaster capitatus, P. paucispinus, Marthasterias sertulifera,* species of *Astropecten* and *Luidia, Linckia columbiæ,* etc.

Among the arctic and in part circumpolar species are *Asterias acervata, A. multiclava, L. arctica, C. cribraria, Allasterias rathbuni, Henricia sanguinolenta, H. tumida, H. arctica, Solaster endeca, Crossaster papposus, Pteraster obscurus,* and var. *octaster, P. militaris, Diplopteraster multipes, Tosiaster arcticus, C. granularis, Leptychaster arcticus, Ctenodiscus crispatus,* etc.

The species apparently indigenous on that coast are too numerous to enumerate here. Some of them are nearly allied to those of the North Atlantic and other regions, but many are very peculiar and have no near allies in other regions, so far as known.

A number of the genera and higher groups are peculiar to that coast, others have there a remarkable development in number and variety of species, showing that their evolution must have gone along continuously for vast periods of time. In many cases primitive and highly specialized species of a family are found associated. Among these peculiar types are *Pycnopodia, Rathbunaster,* several species of *Pisaster,* many species of Asteriinæ, *Dermasterias imbricata, Leptychaster* (*Glyphaster*) *anomalus, Pteraster tesselatus, Bunodaster ritteri,* etc.

Fuller lists will be given at the end of this work, with more details of their distribution.

Class **ASTERIOIDEA.**

MORPHOLOGICAL FEATURES.

The Asterioidea[1] have a polygonal or star-shaped body, in which the rays are direct prolongations of the body itself, and contain extensions of the body cavity and more or less of the viscera, especially one or more pairs of gonads and a pair of digestive glands; generally, also, a lobe of the saccular stomach.

The skeleton is made up of large numbers of ossicles or plates, mostly articulated so as to be more or less movable, giving flexibility both to the rays and to the disk, though in some species (certain Goniasteridæ) the flexibility is slight, except at the tips of the rays.

The actinal side of the disk and rays has deep radial ambulacral grooves, extending to the tip of the rays. The roof of the groove is supported by the two rows of ambulacral ossicles, arranged like rafters, or in close, inverted V-shaped pairs of compressed plates or bars, between which there are rows of pores for the passage of the ambulacral feet.[2]

In the middle line of each ray and external to the ambulacral plates are situated the radial nerve and blood-vessel. The radial water tube supplies water to the locomotive tubes through the medium of muscular ampullæ, usually double, situated internally above the ambulacral plates. In Brisingidæ ampullæ are lacking; in Echinasteridæ they are single.

There is no median row of calcareous plates covering the ambulacral areas and radial nerve and blood-vessel, such as exists in Ophiuroidea.

The tip of each ray ends in a special terminal ocular, or apical, plate, supporting a pigmented ocellus, to which the radial nerve extends. According to the studies of Fewkes, 1888, these are the first plates to appear in the young.

The grooves are bordered on each side by a row of plates called adambulacral, which always bear spines.

[1] This spelling of the name is preferred because it is derived from *Asterias*, not from *Aster*.

[2] In many paleozoic fossil starfishes the ambulacral plates are not opposite, in pairs, but alternate. This rarely occurs in existing species, though I have noticed it in *Pycnopodia* as an abnormal variation in some of the rays, and also that it may occur from lateral bending.

The mouth is central, dilatable, and surrounded by soft membrane. The so-called jaws are merely the adoral ambulacral and adambulacral plates, more or less modified and coalesced; the "teeth" are only slightly modified adambulacral spines, in this work called *peroral spines*. (See text-fig. 3.)

The stomach is very saccular and usually evertible. It usually has a lobe and a pair of digestive glands extending into the cavity of each ray; but in the case of some multiple-rayed species (*Heliaster*), it has lobes corresponding only to the primary five rays. In this case the five stomach-lobes do not enter the rays, but the pairs of digestive glands do. In some slender-rayed genera, also, the stomach is confined to the disk. The intestine is usually nearly or quite abortive and not functionally active. The so-called "anus" is a dorsal pore, chiefly for the discharge of secretions from the dorsal glands, or "cæcal appendages," probably nephridial in function, and called nephridial glands in this work.

Commonly there is a single pair of branched gonads in the proximal part of each ray, with simple ducts discharging through a pair of interradial pores, which may be either ventral or dorsal. In certain Brisingidæ, Luidiidæ, and in a few other families there are several pairs of gonads and genital pores arranged serially along the sides of each ray.

The madreporite or madreporic plate is dorsal,[1] excentric, and commonly single, yet in some multiradiate species there may be several. It is an organ primarily for the purpose of eliminating the excess of absorbed water from the ambulacral tubes and body-cavity.

The sides of the rays and disk are generally supported by two rows of marginal plates, usually larger or thicker than the other plates, and commonly bearing special spines. They are called supramarginals or superomarginals and inframarginals or inferomarginals. (See text-fig. 1.)

The upper row is sometimes much reduced, or obsolete, and rarely both rows are lacking or rudimentary. These rows of plates belong to the primary system of plates, and extend to the apical plate of the rays, like the ambulacral and adambulacral rows.

Plates are constantly added to these rows by the budding in of new plates between the apical plate and the one next to it, the apical plate being pushed farther outward and the ray lengthened at the

[1] In some paleozoic fossil starfishes it is said to be ventral, but it is not so in any living species. The statement by Gregory (op. cit., p. 238, 1900) that it is ventral in *Asterina* is erroneous.

same time. The first median dorsal plate of the rays appears very early in the young, and the first marginals and adambulacrals soon after.

In many genera and families, but not in all, additional rows of plates may be interpolated between the marginal rows proximally, and are called intermarginals; or between the inferomarginals and the adambulacrals, when they are called interactinals, intermediate actinals, or simply actinal plates.[1] These do not appear very early in the young, and are often without spines.

These interactinal and intermarginal plates do not belong to the primary system of plates, nor do they commonly reach the apical plate. Their new plates develop mostly at the tips of the rows, as the starfish grows larger, and new rows may be interpolated till they sometimes become very numerous, in order to increase the size of the rays.

The dorsal skeleton of the disk, in a five-rayed species, primarily has five basal radials (or first dorsals), five genitals, and five pairs of interradial plates, besides the plates that later become the apical or ocular plates, and the centro-dorsal plate. By the interpolation of new ossicles and plates in various ways, the structure often becomes very complex.

On the rays we can usually distinguish a median or carinal row, extending from the basal radial to the apical plate. Other regular rows may develop each side of this (the dorso-laterals), or the whole surface may become covered with a tesselated arrangement, or a reticulated system of plates and transverse ossicles.[2]

The dorsal plates, like the marginals and interactinals, commonly bear spines or small spinules, but they may be covered with granules, or with a smooth soft integument, or even appear quite naked, being then covered only with a thin membrane.

These plates and their armatures of spinules take several special names, according to their forms and structure, and are often characteristic of special genera and families and higher groups.

When they become columnar or of hour-glass shape, and have the summit covered with a radiating cluster of small slender spinules,

[1] For more details of the rows of plates and their sequence, see below, under the family Asteriidæ, and text-figure, 1, i-iv. For the sequence in the early stages of the development of the primary plates, see J. W. Fewkes: On the Development of the Calcareous Plates of Asterias, 1888.

[2] For more details of the skeletal plates, see the discussions under the several orders and families below, especially under Forcipulata and Phanerozona.

they are called paxillæ. These are most typically formed in *Astropecten, Luidia,* and allied genera, and are characteristic of the suborder Paxillosa.[1]

Pedicellariæ of one or more kinds are generally present, but are entirely lacking or very rare in certain families, such as the Solasteridæ, Echinasteridæ, Pterasteridæ,[2] and in some genera of other families. Their uses are imperfectly known. One use is to keep the body free from dirt and parasites.[3]

Another use, perhaps the most important, seems to be, according to my own observations, to retain the discharged unfertilized ova until fertilization takes place, thus preventing their dispersal and loss. This, however, needs further investigations on living starfishes.

These curious organs are not found in other classes of Echinoderms, except in the Echinoidea. In the latter they are commonly mounted on long stalks and generally have three valves, sometimes two to four or even more.

In the Asterioidea they are usually sessile or (Order Forcipulosa) have very short pedicels, and they are most frequently bivalved.

They are of several different types, which are commonly characteristic of the orders and families, and often of the genera.

Sometimes there may be bivalved, trivalved, four-valved, and five-valved ones on a single specimen. (See below, under *Dermasterias imbricata,* and pl. VI, figs. 4, 5 *P, P'*.). In some cases they are not really valvular, but consist of several movable spinules, arranged in convergent groups or opposed rows (pl. XXXIV, *P. P.*). The sessile valvular forms are generally situated over a pore, penetrating a plate, for the passage of nerves, etc. (Pls. XLVII, XLVIII.)

The different kinds take special names. For further details of the pedicellariæ and their special names, see below, under the several orders, and plates LXXV-LXXXV.

In nearly all species there are numerous small, soft, tubular outgrowths from the body-wall, called papulæ, serving for respiratory purposes. They may be in large groups, especially between the

[1] For various other special forms and their names, see below, under Phanerozona and Valvulosa.

[2] In the last two of these three families, and perhaps in the first, the mother carries and protects the eggs and young until they are able to provide for themselves.

[3] The large bivalve pedicellariæ of *Hippasteria* are very muscular. I have lifted a large living starfish of this kind, weighing about a pound, entirely out of water by a toothpick, seized by the jaws of a dorsal pedicellaria.

dorsal and lateral ossicles, or stand singly, or they may occur only in special areas. Rarely they are branched.

Most shallow-water starfishes that have been studied in this respect have a free-swimming, bilateral larval form, known as a brachiolaria; yet a considerable number carry their eggs and young till they develop the starfish form, as explained above. These have an abbreviated metamorphosis. The two methods may occur in different genera of the same family (e. g., *Asteriidæ*).

The embryology of the deep-sea species is unknown in most cases, and may be diverse, or even more abbreviated.

CLASSIFICATION OF ASTERIOIDEA.

In this report I have adopted the division of the class into three large orders, viz.:

I. FORCIPULOSA or **FORCIPULATA.**
II. SPINULOSA.
III. PHANEROZONA.

The last has two suborders, considered orders by some recent writers, viz.:

I. VALVULOSA or **VALVATA.**
II. PAXILLOSA.

Order **FORCIPULOSA** Verrill, or **FORCIPULATA** Perrier.

Stelleridæ forcipulatæ PERRIER, Mém. Etoiles de Mer, pp. 166, 188, 1876. 1884
Forcipulata PERRIER, Expéd. Sci. Trav. et Talisman, p. 27, 1894.
Asteries Ambulacraires VIGUIER, Squellette des Stellérides, Arch. Zool. Expér., VII, p. 93, 1878.
Cryptozonia (*pars*) SLADEN, Voy. Chall., XXX, pp. xxxiv, 397, 1889.
Adetopneusia (*pars*) and *Leptostroteria* (*pars*) SLADEN, op. cit., p. XXXIV.

The form is always stellate, often with long rays, commonly five, but often multiple. Ambulacral plates, except the orals, are usually short and closely crowded (*leptostroterial*), but not in Brisingidæ. The proximal pair is elongated and, except in *Pedicellaster* and a few others, forms the inner end of the jaw. Ambulacral feet are generally arranged in four rows,—but in two rows in Pedicellasteridæ, Brisingidæ, and Zoroasteridæ.

In some large species of *Pisaster* they may form six or more rows by crowding, especially subproximally. They are always terminated by suckers.

Adambulacral plates are generally short and crowded, equal in number to the ambulacrals. They may each bear a single spine (*monacanthid*), or two spines (*diplacanthid*), or alternately one and two (*subdiplacanthid*), or rarely three spines (*triplacanthid*).

The superior and inferior marginal plates are rather small (*cryptozonial*), but are generally distinct and bear spines, often longer than those on the dorsals. In some *Brisingidæ* one row, or rarely both rows, may be lacking. They extend to the apical plate and increase in number during the whole period of growth by the addition of new plates next to the apical.

The dorsal skeleton is variously constituted, but usually consists of plates and ossicles, often very unequal in size and form, so united as to move freely, leaving many papular areas between them. In some of the Brisingidæ and in *Pycnopodia* the ossicles are mostly nearly abortive, roundish, and isolated in the integument.

The plates generally bear spines, either singly or in clusters; sometimes they are reduced nearly to the form of granules; never paxilliform. The papulæ may be few, or many in large clusters. They usually occur both on the dorsal and on the ventral surfaces,—*adetopneusic* arrangement.

The Forcipulosa, as the name indicates, are especially characterized by the presence of very peculiar, pincer-like, two-bladed pedicellariæ, usually of two forms, movably attached to the dermis of the spines, or to the surface between, by means of longer or shorter flexible dermal pedicels.

VARIOUS KINDS OF PEDICELLARIÆ.

Except possibly in a few rare cases, and in quite immature specimens, at least one form of these is always present.

Of the two principal forms, those known as forcipate or "*minor pedicellariæ*" are the most abundant and occur most constantly. Such pedicellariæ do not occur on starfishes of any other order. Those nearest analogous occur on certain *Echinoidea*.

In the larger kind, called "*major pedicellariæ*" by Stimpson;[1]

[1] I prefer to use ordinarily the names first given by Stimpson, in 1861, for the two principal forms of pedicellariæ, viz., *major pedicellariæ* and *minor pedicellariæ*. These terms are sufficiently descriptive, and not so liable to be confused as those proposed later by Herapath, though the latter have some advantages. It is desirable, however, to have some additional special descriptive terms for varieties of each sort. Either form may be attached to the spines or to the general integument. The minor pedicellariæ that surround spines in wreaths, may be called *circumspinal;* those in smaller irregular clusters on the spines, *epispinal;* those attached to the general surface of

"*pedicellaires droites*" by Perrier, 1869; and "*forficiform pedicellariæ*" by Herapath, 1866, and by Sladen, 1889, the jaws are nearly straight, articulated at the base by a simple joint to a thick basal piece, so that they open and close like forceps. These may be either dermal or attached to the spines, either singly or in clusters; they often have short pedicels. In the *Brisingidæ* and in *Pedicellaster* they are usually lacking. (See pl. XLIX, figs. 3-3*d*; pl. XXX, etc.)

The second kind, called "*minor pedicellariæ*" by Stimpson, "*pedicellaires croisés*" by Perrier, "*crossed pedicellariæ*" by several writers, and "*forcipiform pedicellariæ*" by Herapath, are usually much smaller and the blades are curved and crossed something like those of scissors, and so articulated that they open and close like scissors, tweezers, or pincers. These, like the others, may be attached directly to the integument, either singly or in clusters, or to the spines, to the pedicels of the larger forms, to saccular dermal growths around the spines, to the inner edge of the ambulacral grooves, or rarely even to the sucker-feet. (See plates LXXVI-LXXXIV.) They are most commonly attached by slender and sometimes long pedicels, and aggregated into wreaths or clusters on the spines. They are often so abundant, in the wreaths around the dorsal spines, that they nearly or quite conceal the spines and integument in living specimens. In some cases they are attached in large numbers to dermal sheaths or sacks loosely surrounding the spines. They often have a formidable array of minute sharp denticles, and are frequently very characteristic of species. (See text-fig. 2.)

FAMILIES AND SUBFAMILIES OF FORCIPULOSA.

This order now includes the following families and subfamilies:

Family *ASTERIIDÆ*.
  Subfamilies *ASTERIINÆ; STICHASTERINÆ; PYCNOPODIINÆ*; HELIASTERINÆ.
Family *ZOROASTERIDÆ*.
Family *PEDICELLASTERIDÆ*.
Family *BRISINGIDÆ*.
  Subfamilies *BRISINGINÆ; LABIDIASTERINÆ*. (Type, *Labidiaster* Lütk.)

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the body are *dermal;* those on a papular area are *papular;* those on the adambulacral spines or plates are *adambulacral.* Major pedicellariæ may also frequently occur within the adambulacral grooves, attached to the inner surface of the adambulacral plates, where they may be called *intra-adambulacral.*

Family *ASTERIIDÆ* Gray (emended).

Asteriidæ Gray, Ann. Mag. Nat. Hist., VI, p. 178, 1840; Synopsis, p. 1, 1866. Perrier, Revis. Stell., Arch. Zool. Exper. et Gén., IV, p. 302, 1875; Mém. Etoiles de Mer, pp. 167, 198, 1876. Viguier, Squelette des Stellérides, pp. 93, 99, pl. V, figs. 1-10, 11-12, 1878.

Asteriidæ (emended) + *Stichasteridæ* Sladen, Voyage Chall., XXX, pp. 430, 560, 1889. Perrier, Exp. Trav. et Talisman, pp. 43, 105, 107, 128, 1894; Contrib. l'étude des Stellérides Atlan. Nord, pp. 25, 31, 1896.

Rays five to twenty or more, but most frequently five or six. Madreporic plate generally single in five-rayed and six-rayed forms, but often two or more in those with a variable number of rays. Dorsal and actinal plates various in form and arrangement. Odontophore usually formed of a single piece. Oral ambulacral plates elongated; those along the grooves become very short and compressed. Papulæ occur both on the actinal and dorsal sides. Ambulacral feet usually crowded in four rows, sometimes more. Pedicellariæ of two kinds are present. Dorsal ossicles generally bear spines or spinules, various in size and kind, and sometimes granules. They are never true paxillæ.

The mouth is large; the stomach saccular and evertible; intestine rudimentary or abortive. A subcentral, dorsal pore (nephridial pore) is present, through which is discharged the secretion of the branched or lobular "rectal" or nephridial glands, which are usually unequal and often but two or three in number. This pore is usually called the "anal pore," but rarely, if ever, functions as an anus in this family. The intestine is nearly or quite abortive, in most cases.

I. MORPHOLOGY OF THE OSSICLES.

Aside from the ambulacral and adambulacral plates, the skeleton of the rays consists of five fundamental or primary rows of ossicles, viz., the *median dorsal* or *carinals;* the two *superomarginals;* and the two *inferomarginals.* The latter may or may not be confined to the ventral side. (See fig. 1, i.)

The ossicles of adjacent rows may be articulated directly by their lobes, or either large or small, simple *connecting ossicles* may intervene.

This simple or primitive type of skeleton is found in *Heterasterias volsellata* (Sla.), and in a few other species, especially when young.

In most cases more or less numerous ossicles or rows of ossicles are interpolated during growth between the five primary rows, either above or below, or between the marginals, thus giving rise to many

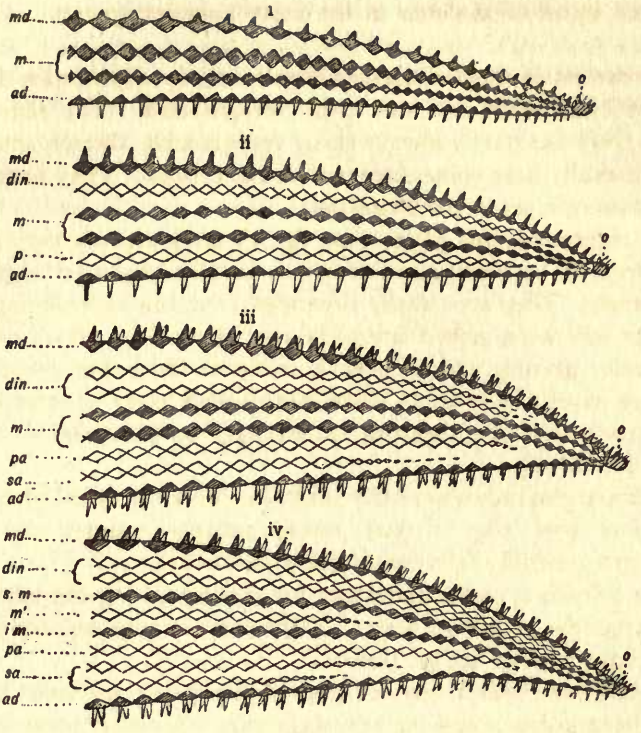

FIG. 1.

Diagrams generalized to illustrate progressive ontogenetic and phylogenetic development of the plates and spines in the rays of starfishes (*Asteriidæ*). Lettering as follows; the primary rows are shaded:

md, Median dorsal or carinal row. *m*, Marginal rows. *m'*, Intermarginal row. *sm*, Superomarginal row. *im*, Inferomarginal row. *ad*, Adambulacral row. *din*, Dorsal-intermediate, medio-lateral, or dorso-lateral rows. *p* or *pa*, Peractinal row of plates. *sa*, Subactinal rows. These and the peractinals are the *interactinal* plates, collectively. *o*, The ocular, apical, or terminal plate.

i, The simplest or most primitive condition, common in the young; uncommon in the adults, in which only the primary rows of plates are developed.

The longitudinal area between *ad* and the next row is called the perambulacral *lane* or *channel;* the space between the marginals (*m*) is called the intermarginal *lane* or *channel;* the area next above the upper marginal is called the supramarginal *lane* or *channel*. These "lanes" or "channels" are always crossed by transverse connective ossicles or by overlapping lobes of the plates, dividing them up into larger or smaller *papular areas*, and they usually bear more or fewer of the larger pedicellariæ in the Asteriidæ.

ii, The condition, more advanced, in which the peractinal row (*p*) and one medio-lateral row (*din*) are developed. A common condition in the Asteriinæ. This is called the *monoactinoplacid* condition.

iii, A more advanced condition in which an additional interactinal row (*sa*, subactinal) and a second dorso-lateral or medio-lateral row (*din*) have appeared.

iv, A more complex state, in which there are two subactinal rows (*sa*), and an intermarginal row (*m'*).

This is a common condition, but more medio-lateral rows are often added, as well as more subactinals, in such genera as *Pisaster, Evasterias*, etc. This is called the *polyactinoplacid* condition. All these plates usually bear spines, one or more each. They may be easily visible or they may be entirely concealed by a thick tough skin. The peractinal or subactinal plates, when thin or small, may be destitute of spines and stand edgewise, ao as to show only the edge at the surface, or they may be so closely joined to the inferomarginals as to require cleaning with potash to be seen.

different styles of skeleton in the more complex genera. (Fig. 1, ii-iv.)

The carinal or median dorsal plates (*md*) usually remain distinct, but are often small and not easily recognizable. The superomarginals (*sm*) are nearly always easily recognizable, though small, and they generally bear spines larger than the dorsals. They never form a stout margin, as in the Paxillosa.

The inferomarginal plates (*im*, fig. 1) are generally very evident and carry one or more rows of spines usually longer or larger than the dorsals. They are usually separated from the superodorsals by a more or less wide, naked lateral lane or channel on which are rows of papular groups, and frequently many of the larger pedicellariæ. In some cases one or more short intermediate rows of lateral plates (intermarginals, *m'*), bearing spines, may be interpolated in these areas, proximally.

Both marginal rows normally reach the ocular or apical plate. The peractinal row (fig. 1, *pa*) rarely actually touches the apical plate, and generally falls considerably short of it.

This affords a useful character for distinguishing the inferomarginal from the *peractinal* plates.[1] This name is proposed for the first or primary row of actinal plates.

To designate collectively the rows of plates that may exist between the inferomarginals and the adambulacrals, I propose to use the term "*interactinals*" in place of the longer one, "*intermediate actinals*," used by Sladen and others. I would do away with the use of the words "*actinal spines*" or plates used by many writers as including the inferomarginals with the true actinals. *Ventrals* may be less objectionable if such a collective name be needed, and is so used by Perrier and others.

The upper marginal row of ossicles is usually pretty clearly defined by special spines. This superomarginal row usually diverges from the lower one, or turns upward at the base of the rays, and may run a little upon the dorsal surface to join its counterpart on the next ray at the dorsal interradial angle or axil. The plates here called subactinals (text-fig. 1, *sa*) appear later than the peractinals. They are often lacking in the young, up to 30 to 50 mm. in diameter, even when they are present in the adult. They often extend only on part of the ray, proximally. The number of rows of these in large species increases with the age.

[1] It seems desirable to have special and convenient terms to designate the several series of plates and spines in this and related families.

The row of actinal plates that unites with the adambulacrals, when there are several rows, may be called *synactinal,* to indicate its function. It may consist either of the peractinals or of subactinals.

When these rows are very much alike in size and form, mistakes have often been made in descriptions, the peractinal row having often been described as the inferomarginal row or vice versa, or else no distinction has been made by the earlier writers.

The most positive criterion, in doubtful cases, is to trace these rows of plates to their origin. True marginal rows originate at the ocular plate; peractinals, when present, often terminate near the ocular; but other rows generally fail to reach the end of the ray.

The inferomarginal plates may be directly joined to the adambulacrals by a lobe or apophysis, but more commonly there is at least one row of actinal plates between, and sometimes, besides this first or *peractinal* row (*pa*), there may be one or more shorter rows of *subactinal* plates (*sa*) interpolated proximally. All these plates usually bear spines, but in some cases all the interactinal plates are rudimentary and spineless.

The secondary dorsal skeleton varies much, but is most commonly chiefly made up of unequal and more or less imbricated ossicles or lobulated plates, with the ends or lobes of adjacent plates overlapping, so as to leave rather wide papular spaces between them. Or the plates may be broader, somewhat rhombic, lobed, and more closely imbricated, as in *Stichaster.* In most cases, however, they are also united transversely by smaller connective ossicles.

II. PEDICELLARIÆ OF THE ASTERIIDÆ.

Text-figure 2.

Pedicellariæ of both kinds are probably always present in the normal adults, though on some individuals they may be few or lacking.

The major or forficulate pedicellariæ are generally ovate or lanceolate, sometimes wedge-shaped, stone-hammer-shaped, lyrate, or spatulate. The tips may be acute, plain, flat, or denticulate.

They are mostly dermal, but may also occur on the ventral and oral spines, or along the inner edges of the grooves, or attached to pedicels in clusters within the grooves, or even on the pedicels of the ambulacral feet. They may be of several sizes and forms on one specimen.

Certain species of *Stichaster, Coronaster,* etc., have a peculiar very large form of dermal pedicellariæ, often as thick as the spines, in

which the broad valves terminate in a series of curved denticles, so that when closed the valves resemble a pair of clasped hands, or better still, a pair of clasped feet of a cat, with the claws protruded. These may be called *felipedal* or *unguiculate.* In many other cases similar gigantic pedicellariæ have spatulate valves, with a smooth or denticulate edge. In *Pisaster* they are sessile, stout, erect, stone-hammer-shaped or wedge-shaped, with serrate or unguiculate edges. (See pl. XLIX, figs. 3-3*b*.)

These peculiar giant forms are usually accompanied by others of the ordinary ovate form, much smaller in size, and they are usually characteristic of special generic groups. But as such groups are sometimes widely separated, both morphologically and geographically, it is not unlikely that these are survivals of a type of pedicellariæ that, at some remote period, was common to the whole family.

The minor or forcipulate pedicellariæ (text-fig. 2) generally form wreaths or large or small clusters on the spines, but they may also occur, either singly or in clusters, on the integument of the dorsal or lateral plates, on the papular areas, and in other situations.

III. RELATIVE IMPORTANCE OF MORPHOLOGICAL CHARACTERS IN ASTERIIDÆ.

Perrier, Sladen, Bell, and others who have divided this family, have differed considerably in their estimation of the relative importance of the various morphological characters.

A. MODES OF GROWTH AND INCREASE IN NUMBER OF SKELETAL PLATES.

Text-figure 1, i-iv.

The number of ossicles and plates of nearly all kinds, except the primary radials and orals, and the oculars, increase continually during the entire growth of most starfishes. The size and age have no definite limit, so that unusually large specimens of any species may often occur with correspondingly increased numbers of plates and spines. Therefore the exact number of plates, say of marginals, is of no great importance, except when specimens of identical sizes or ages are compared. In the early stages of growth, the first dorsal plates that appear are the central, primary interradials, the radials, and the ocular plates. A little later the median dorsal radials and the marginals appear; and the commencement of a row between the upper marginals and median row often appears at the same time or a little later. The number of the plates in all the primary rows is

increased by the formation of new plates between the apical terminal or ocular plate and the plate next to it, the oculars being forced farther away as the numbers and growth of the plates continue to increase. But besides the primary rows of plates, other rows and scattered ossicles may appear, to fill up the dermal spaces produced by the increasing diameter of the rays and disk. In some forms of starfishes this is accomplished largely by the rapid growth of the primary plates, which may thus become very large, but this produces a rather inflexible skeleton. In the Asteriidæ flexibility seems to be an essential feature, especially as most of the species cling to irregular stones and similar objects, and rarely live habitually on smooth mud or sand. Therefore, the skeleton has come to be completed in this group by the constant addition of small ossicles movably articulated between the rows of larger ones, especially on the dorsal surface, both longitudinally and transversely.

These later interpolated ossicles may form regular or irregular longitudinal rows between the median and marginal rows, or they may be so interpolated as to form a more or less regular reticulation; in other cases they may be entirely irregular, with no determinate arrangement, seeming to be introduced wherever needed at the time.

These variations in the modes of interpolation of the plates, together with their forms, which may vary from linear to broad, angular, lobate, and scale-like forms, combined with variations in the spines, give rise to the great variety of structures and forms seen in the dorsal surface of starfishes of this family.

Moreover, in most species, the rapid increase of the dorsal skeleton alone apparently does not give sufficient space for the rapidly growing internal organs, especially the reproductive organs, within the bases of the rays, and therefore new rows of plates (fig. 1, iii, iv) must be interpolated between the inferomarginals and the adambulacrals, and sometimes between the upper and lower marginals, to increase the diameter of the rays. The most constant of these rows is that which I have designated as the *peractinal* (*pa*). This row appears very early in many species and often nearly reaches the tip of the ray, but usually not quite to the ocular plate. But the other actinal rows (subactinals or interactinals) (*sa*) are successively shorter and often do not reach the middle of the ray. The plates situated proximally in these rows appear earliest, and new ones are added at the distal end of each row. This is also the case with the interpolated dorsal and lateral rows. In many species,

as in those of *Pisaster,* the number of interpolated interactinal rows (*sa*) goes on increasing during the whole or most of the period of growth, so that in large specimens there may be four or five rows on each side. But in many other species the number of rows is fixed very early, the young, two inches in diameter, having as many rows as those six to eight inches in diameter, the subsequent increase in size being due to the enlargement of the plates and the formation of new ones dorsally and distally. But in many species with long, slender rays the peractinal plates alone are developed, and in a few even these are lacking, or else so small as not to be visible externally, as in *Urasterias linckii,* etc. So, likewise, in other long-rayed species, the dorsal skeleton may lack more than one pair of interpolated rows of ossicles, as in *Coscinasterias.*

B. INTERACTINAL PLATES AND SPINES.

Text-figure 1.

The presence or absence of actinal plates and spines, and whether one row or several rows of these plates be developed, are characters that often seem to be of generic value. Those forms that have no such plates at maturity, or have only one imperfect row, are probably the more primitive types, or at least they have probably inherited and preserved this primitive character. The very young starfish in all the genera apparently has none of these plates, but acquires them as growth proceeds. They are lacking or rudimentary in *Urasterias, Distolasterias, Stylasterias,* and some other groups. They exist in only one row in *Orthasterias, Coscinasterias,* etc. In true *Asterias* and some other groups, one or two, or more, incomplete subactinal rows are usually added. In *Evasterias, Pisaster,* and *Cosmasterias,* two, three, or more rows are present. In those species that have subactinal plates, these increase in number during the whole period of growth, and new rows may also be added continually. Nevertheless these plates seem to afford morphological characters of much value in classification, and they are usually coincident with other special features. It is of great importance that correct distinctions should be made between the *actinal, inferomarginal,* and *supramarginal* plates and spines. This has not been done in most of the earlier descriptions. Side views of the rays are necessary to show these plates properly, but such views are rarely given. In many species they are without spines and so concealed by thick skin that they cannot be determined without preparation, and therefore are not visible in alcoholic specimens.

C. FORM AND ARRANGEMENT OF THE DORSAL OSSICLES.

The form and arrangement of the dorsal ossicles vary considerably and often afford characters of much value. Aside from the stichasterial arrangement, there are two main types,—the reticulate and the longitudinal,—in both of which the principal plates are lobed, substellate, or cruciform. The former, which is seen in true *Asterias, Pisaster,* etc., includes several subtypes,—as the stellate-reticulate, seen in *Pisaster fissipinus;* the areolate, seen in *E. troschelii;* and the irregular or indeterminate, seen in *Asterias vulgaris, A. rubens,* etc. These variations depend partly upon variations in the forms of the plates and partly on their arrangement and the existence of supplementary ossicles, and especially on the size and the form of the papular areas.

The abactinal skeleton of the longitudinal type may consist of only three rows of stout dorsal plates, besides the marginals, with few or no supplementary ossicles, as in *Coscinasterias;* or the median may alone remain distinct, as in some species of *Urasterias.* But in other related groups there may be five or more regular rows. These last have but three rows when quite young, so that the forms with three rows are probably more primitive. *Urasterias* may be still more primitive. Its skeleton is very likely a degenerate type. In the stichasterial arrangement the plates become broader, more angular, and less lobed, and they are usually united directly together by their overlapping or adjacent edges in rather regular, longitudinal, imbricated rows; or they may have a tesselated arrangement. The intervening papular areas are consequently small and rather regularly arranged.

D. DORSAL SPINES; FORM AND ARRANGEMENT.

The number, form, and arrangement of the dorsal spines vary widely. Their arrangement, when coincident with that of the plates, is a matter of much importance, but widely different appearances may occur in a single species, due to the variable number of spines that may occur on a single plate, combined with their variations in size and shape. No character is more likely to lead to mistakes in the determination of species and genera than the appearance of the dorsal spines, especially in those groups which, like restricted *Asterias,* have very numerous spines with an indeterminate or irregular arrangement. But in forms that have a limited number or regular arrangement of plates, the spines often conform strictly to

the plates, each plate bearing one or two spines, and then they may be very reliable guides, in case the specimens are adult. The number of plates or spines in a row, and often, also, the number of rows, increase with age. The supplementary or connective ossicles, when present, also increase with age, and may bear corresponding spines.

Mr. Bell, in his arrangement (1881, p. 502), made a special distinction between those species that bear certain spines on isolated or special dermal ossicles (*autacanthid*) and those that bear spines only on the regular skeletal ossicles (*typacanthid*). But the special dermal ossicles, at least in most cases, seem to be merely new skeletal ossicles in process of formation, which are destined, a little later, to become articulated with the older ossicles. Hence this character seems to be of little importance and variable according to the age of the specimens, in most species.

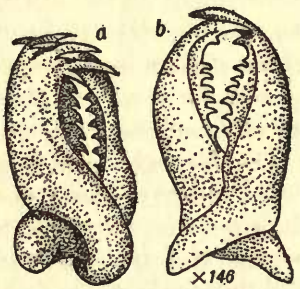

FIG. 2.

Minor pedicellariæ of *Pycnopodia helianthoides* (*a*, *b*); profile views. × 146.

The dorsal and marginal spines may be similar or dissimilar. The spines may be large and long, or slender, short and thick, or capitate. They may stand singly on the plates, or in groups, or they may be reduced to the form of small spinules covering the plates in large numbers, or even nearly to granules, but they do not form paxillæ nor pseudopaxillæ.

E. PEDICELLARIÆ; SPECIAL FORMS.

Peculiar or unusual forms of major pedicellariæ occur on many species, and sometimes species of the most diverse structures and belonging to widely separate faunæ will agree in having some of the felipedal type, mentioned above. Such special forms of pedicellariæ are doubtless of great value for indicating community of origin and generic affinity, when they occur on species that are otherwise structurally similar; but they must not be made to overshadow other structural features, for that would lead to absurd results, as bringing

together such unlike forms as *Coronaster* of the North Atlantic and *Stichaster* of the South Pacific—forms that evidently belong to distinct families. In the case of *Pisaster,* our eight species, though so different in their dorsal spines, all have similar and peculiar erect, stout, unguiculate pedicellariæ of a type rarely to be found in other groups.

Some of the remarkable forms of pedicellariæ are probably survivals of such structures present in remote ancestors, common to this and the allied families in former geologic periods, rather than structures independently developed in diverse genera, now living in different oceans. Their complexity of structure seems to be too great to have arisen independently in modern times.

F. MADREPORITE OR MADREPORIC PLATE, AND SURROUNDING SPINES.

Several writers have made considerable use of the character of this plate. In some of the species having more than six rays, or a variable number, there may be two or more madreporites. Such species are also, in most cases, subject to fission, as in *Coscinasterias, Stephanasterias,* etc. The number of madreporites is variable in each species of this kind, while closely related species may have but one. The madreporite is sometimes surrounded by a definite circle of special spines (*echinoplacid* Bell),[1] but in closely related species no such regular circle of surrounding spines exists.

In some cases different specimens of the same species may vary in this respect. Therefore it cannot be considered a character of more than specific value, and sometimes not even varietal. Bell, in his arrangement, appears to have given too much importance to it. The same remarks, as to variability, apply to a naked groove or narrow channel that sometimes surrounds the plate. The relative position of the plate and the number and arrangement of its gyri vary in different species, and also greatly with age, but are of some specific value in certain cases, as is also its color, in life.

G. JAWS AND ORAL SPINES.

Text-figure 3.

The jaws in this family consist of an apical jaw-plate, composed of the first and second pairs of adambulacral plates closely united

[1] Among the northwestern American species that are usually "*echinoplacid*" are *L. æqualis, A. katherinæ, A. acervata, L. epichlora* (variable), *L. coei, E. troschelii* (variable), etc. In general, species with small and numerous spines are apt to have this character. It is particularly conspicuous in *Cosmasterias lurida.*

together and usually bearing six *oral* spines. The four terminal spines (*peroral spines* or *papillæ*) are directed more or less horizontally over the mouth (*a, a'*); the two outer ones (*a'*) are divergent and smaller and are sometimes lacking. The outer angle of the jaw, formed by the second pair of adambulacral plates, bears an erect and usually longer pair of (*epioral*) spines (*e, e*).

The characters of these oral spines and plates often afford good specific distinctions, and in some cases at least are of generic value; but they have not yet been described or figured with care, except in a comparatively small number of species, so that at present their

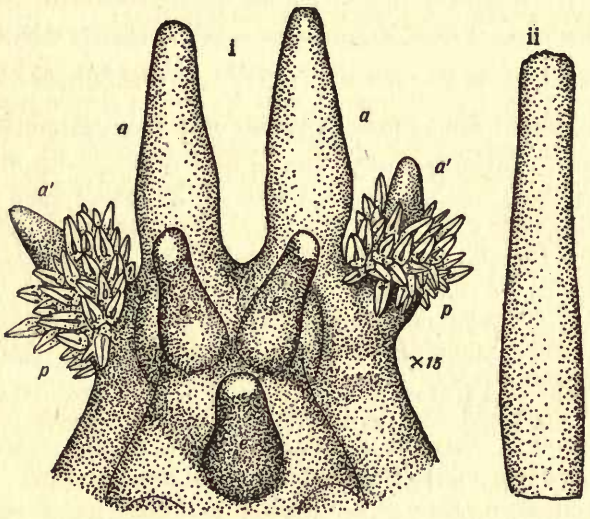

FIG. 3.

Orthasterias californica V., type. i, A jaw; *a, a; a', a'*, apical or peroral spines with pedicellariæ (*p, p*); *e, e*, epiorals; *e'*, odd epioral; × 15; ii, an adambulacral spine. × 15.

value is somewhat uncertain. In general characters they are remarkably constant throughout this family, and in species that differ widely in other respects. This would indicate that their special arrangement has persisted for a very long period of time, for it must have been established before the world-wide dispersal of the family took place, and probably before the family itself was differentiated.

In the calcareous peristomal ring the jaw-plates, formed by the union of two ambulacral plates, are usually more prominent than the plates alternating with them, known as the *odontophores,* formed by the union of two interambulacral plates. Such an arrangement is

called an "*adambulacral jaw,*" and it is characteristic of the family Asteriidæ and of most other families of Forcipulosa.

External to this proper jaw-plate are a series of two to ten or more pairs of *adoral* adambulacral plates, each pair closely pressed together (contingent), to form the *adoral carina,* which may be more or less compressed and thin, and is longest in those species with a large disk, like the *Pisasters,* in which it often contains ten or eleven pairs of united plates. The spines (*adorals*) borne on these plates are often longer than those beyond.

H. ADAMBULACRAL SPINES; ARRANGEMENT.

Much importance has been given by many writers to the number of adambulacral spines on each of the plates. Many species have regularly a single spine on each plate, thus forming a simple regular row (*monacanthid*). Others have regularly two spines to a plate, forming two rows (*diplacanthid*). But still more frequently the spines stand irregularly, one or two to a plate, or alternately one and two, (*subdiplacanthid*). In these the spines often appear to form three rows. In *Allasterias* Ver. the inner spine is situated higher up within the groove, on alternate plates.

In some cases, as in *Pisaster* and *Coscinasterias,* the monacanthid condition is associated with other important characters, and in these it seems to be really of generic value; but it should not be used as a character of primary importance, nor by itself, for generic divisions, for in some cases closely related species, or individuals of the same species, may differ in this respect.[1] Yet it is a character ordinarily early fixed in the young starfish, and therefore important.

I. NUMBER OF RAYS; VARIABILITY.

The number of rays can only be used for subordinate purposes, for it is apt to vary sporadically, even in species that are the most constant, like *Asterias vulgaris* and *A. forbesi* of the Atlantic coast, in which we find, when vast numbers are examined, that a certain per cent will have six rays, and a smaller per cent seven rays and four rays, while eight-rayed and even nine-rayed examples may occur very rarely; but those cases with seven and more rays may, in most cases, be due to abnormal repairs after injury.

In certain species of *Leptasterias* that carry their eggs and young till they reach the period of bottom life, the young carried by the

[1] This is true of *Coscinasterias tenuispina* and *C. acutispina* (Stimp.).

same parent may have different numbers of rays. Thus those carried by six-rayed parents of *L. epichlora alaskensis,* were found to be mostly six-rayed; but about five per cent were five-rayed, and a few were four-rayed. (See below, and pl. LXXXV, figs. 2, *a-f.*)

In other species and genera the number of rays is extremely variable, as in *Coscinasterias,* where they vary indifferently, from six to eleven or more. In *Pycnopodia,* additional rays bud in between the older ones in pairs during growth, so that the adult may have twenty to twenty-four rays. This variation is complicated in most species of the former group, and in *Stephanasterias albula,* by their remarkable habit of spontaneous fission (autotomy) and subsequent irregular replacement of the lost rays by each half. (See pls. LXXIII and LXXIV.)

J. ARRANGEMENT OF THE AMBULACRAL FEET OR SUCKER-TUBES.

These are generally arranged in four crowded rows in each groove, or sometimes in two zigzag rows, one on each side of the median line. But in many of the larger species with broad rays, as in the genus *Pisaster,* they may form six or even eight rows, especially subproximally. *Pycnopodia* has four rows of sucker-feet subproximally, and two rows proximally and distally when adult.

K. MODES OF DEVELOPMENT; BROODING OF THE YOUNG; POSITION OF THE GENITAL PORES.

Two widely diverse methods of development occur in the Asteriidæ, as described above (p. 7). So far as now known, those genera that carry or brood their eggs and young (*pædophoric species*) also have their genital pores situated on the actinal side, near the mouth; while those that disperse their minute eggs, and whose young undergo a prolonged, free-swimming larval existence, have the genital pores in the dorsal interradial areas. It is probable that this difference is the most important morphological character by which the family, or at least the Asteriinæ, can be divided into large generic groups. Unfortunately this feature has not been noted nor studied except in the case of a small number of the genera and species, so that at present, it can be utilized only in a limited number of genera.

CLASSIFICATION OF ASTERIIDÆ.

As defined above, the Asteriidæ would include, as subfamilies, Asteriinæ, Stichasterinæ, Pycnopodiinæ, and Heliasterinæ=Heliasteridæ Sla.

Subfamily *HELIASTERINÆ.*

Subfamily *Heliasterinæ* VIGUIER. Family *Heliasteridæ* Perrier; Sladen.

The Heliasterinæ do not seem to me to be worthy of more than subfamily rank. They agree with Asteriidæ in nearly all important structural characters. They differ mainly in having very numerous short rays and a very broad disk, but in these respects they are closely approached by *Pycnopodia* and *Cœlasterias.* Their dorsal, ventral, and ambulacral skeletons are distinctly like Asteriidæ. The only distinctive characters of much value are the restriction of the stomach to the disk by a discobrachial septum, and the existence of double septa between the rays.

The group, which includes only the genus *Heliaster,* is confined to the Pacific coast of America and the adjacent islands, from Chile to Lower California. (See H. L. Clark, op. cit., 1907, plates I-VIII, for details of structure and descriptions of all the species.)

Subfamily *PYCNOPODIINÆ.*

For the characters of this subfamily, see below, p. 197.

Subfamily *STICHASTERINÆ.*

The most developed forms of Stichasterinæ,[1] e. g., *Stichaster striatus* = *aurantiacus,* have several regular rows of interactinal plates; other forms have only one or two rows. Some of the Asteriinæ (*Cœlasterias, Pisaster,* etc.) also have from three to six rows of such plates. On the other hand, some forms of Stichasterinæ (*Stichastrella rosea, Stephanasterias albula,* and *Granaster*) have the dorsal ossicles more or less irregularly arranged; and even the median row may not be distinct in *S. albula.* In the latter the ventral plates bear longer spinules. *Cœlasterias* V. is an intermediate genus with multiple rays.

The Stichasterinæ have, at present, no known representatives on the northwestern coast, unless we so reckon the *Stephanasterias*

[1] *Stichaster* M. and Tr. (April, 1840) was monotypic. Its type was *S. striatus* M. and Tr. = *Asterias aurantiaca* Meyen (*not* of Linné) = *Tonia atlantica* Gray (Sept., 1840). *Tonia* is a complete synonym of *Stichaster,* which has about six months priority. The European species, *A. rosea,* usually referred to *Stichaster,* and taken as its type by many writers, is a distinct genus which, so far as I know, has no valid name. It may be called **STICHASTRELLA,** *S. rosea* being the type. It has two or three rows of interactinal plates; adambulacral plates bear two or three spines irregularly. Carinal rows of plates and spinules are usually distinct, but only by the slightly larger size of the plates.

albula,[1] which is a very widely distributed North Atlantic and Arctic species, which has been found at moderate depths off the northern Alaskan coasts. I consider it one of the Asteriinæ, allied to *Leptasterias.*

It is autotomous while young, with a variable number of rays, but when large it is usually regularly six-rayed.

The consideration of the importance of the stichasterial or imbricated arrangement of the dorsal ossicles early led to the separation of *Stichaster* as a genus, and later as the type of a family, but perhaps even that character does not always indicate close affinity nor an identical origin, for it may have been developed independently in different regions and in distinct lines of descent. As a matter of fact, we find the greater number of the species, and those that are the larger and more typical, living in the Antarctic seas and on the southwestern coast of South America, while only a few rather small and less characteristic forms exist in northern seas.

It is not unlikely that the northern forms, like *S. rosea* and *S. albula,* originated entirely independently of those of South American seas, and should, therefore, be classed as distinct genera. This is indicated, moreover, by their morphological characters. *S. albula,* especially, differs but little from some forms of *Lepasterias,* and may well have been developed from some member of that or a similar group. Its embryology is not known.

However, all recent investigators admit that the stichasterial arrangement of the dorsal ossicles is at least of generic value.[2]

Other variations in these plates may be of equal value.

The discovery of many new generic and specific types intermediate between typical *Stichaster* and *Asterias,* as already intimated, renders it difficult to define the limits of the two so-called families, typified by these genera.

[1] This is the *Asterias albula* (Stimp.) = *Stichaster albulus* Ver. = *Stephanasterias albula* Ver. = *Stichaster albulus* Sladen = *Nanaster albulus* Perrier, 1894, p. 131. It is found from the Arctic Ocean to South Carolina and Georgia, in deep water, on the east American coast, and as a littoral species it occurs as far south as the Bay of Fundy. It is also common on the northern European coasts.

[2] Sladen has even gone so far (op. cit., p. xxxvi, 1889) as to widely separate Stichasteridæ and Zoroasteridæ from the Asteriidæ on this character, almost exclusively, placing them between Linckiidæ and Solasteridæ—families that do not belong to the Forcipulata. This seems to me a very unnatural arrangement, due to overestimating the importance of the character of the dorsal ossicles.

Sladen and Perrier disagree both as to the character and limits of the two groups, because certain genera and species present characters of both groups, or have intermediate characters. Therefore it seems necessary to reunite them in one family. However, it may be convenient to retain the groups as subfamilies or sections with no very definite limits.

A pseudostichasterial condition is sometimes produced by the existence of clusters of spinules in regular rows, on the transverse dorsal connective ossicles. This cannot always be determined without removing the investing integument.

Perrier considered the characters of the dorsal spinules as of paramount importance in this group. He would place all the genera with distinct spinules or spines in Asteriidæ, and those with granule-like spinules in Stichasteridæ;[1] but in fact there are all intermediate gradations in the character of the armature, and it is often difficult to say whether these structures, in some species, should be called "granules" or "spinules." This seems to me a character only of specific value.[2]

Subfamily *ASTERIINÆ.*

Asteriidæ (restr.) SLADEN, op. cit., 430, 560, 1889. Perrier, 1894, pp. 105, 128; 1896, pp. 25-31.

As here limited this subfamily corresponds nearly with the restricted family Asteriidæ in the systems of Sladen and of Perrier.

The Asteriinæ[3] are chiefly characterized by the more or less openly reticulated arrangement of the dorsal and lateral ossicles, especially of the dorsal ossicles, which are usually more stellate or lobulate and more slender than in the *Stichaster* group, and generally united either by the ends of the lobes or apophyses, or else by means of interpolated ossicles, thus allowing more flexibility in the rays, and larger papular areas.

The Stichasterinæ, on the contrary, are chiefly characterized by the more or less regular subtesselated or imbricated arrangement of the

[1] *S. gracilis* and *S. albula*, with other related forms, have definite spines.

[2] The genus *Calvasterias* Perrier, 1895, has about five series of lobed and imbricated, flat dorsal plates, bearing few small short spines, and entirely covered with a thick, naked, soft, canaliculated dermis.

The character of the plating should cause it to be placed in the Stichasterinæ.

It is monacanthid and there is a row of small spiniferous, interactinal plates, at least in *C. stolidota* Sla., of Chile and the Falkland Islands.

[3] This form of spelling the word seems necessary, because it is derived from *Asterias*, not from *Aster*.

ossicles, both on the sides and dorsal surface of the rays, the ossicles themselves being larger, broader, and more rhombic, and usually united in more definite, longitudinal rows, with smaller and more regular intervening papular areas. In either group, as at present understood, the interactinal or ventral plates may have the regular serial and subtesselated arrangement.

A. GENERIC SUBDIVISIONS OF ASTERIINÆ.

The genus *Asterias,* in the wider sense, as still used by many writers, includes a very large number and a great variety of species, found in all seas. Various attempts have been made to divide the genus into a number of genera or subgenera on structural characters, but hitherto there has been no general agreement among writers, as to the number or limits of most of the subdivisions. Nor do I flatter myself that my own views will be altogether acceptable.

One of the best known classifications hitherto proposed is that of Sladen.[1]

He admitted, in the restricted family Asteriidæ (our Asteriinæ), five distinct genera, including *Pycnopodia.* Under *Asterias* he had six subgenera. Most of these are undoubtedly worthy of generic rank. One of them (*Leptasterias*) had been proposed as a genus by the present writer, many years earlier, and another (*Stolasterias*) is essentially identical with our *Coscinasterias,* 1867. His subgenus *Hydrasterias* is evidently a distinct genus, peculiar to the deep seas, and has already been so recognized by Perrier and myself. Perrier, in a later work,[2] recognized all of Sladen's divisions as genera, but with the limits modified in some cases, and proposed four more generic subdivisions, some of which seem to have no great systematic value. This is particularly true of *Diplasterias,* separated from *Asterias* mainly on account of the two regular rows of adambulacral spines,—a character that is variable in this group and often of no more than specific importance, taken alone. Many species of *Asterias* have alternately one or two adambulacral spines, and others have irregularly one and two to a plate. *C. tenuispina* is generally strictly monacanthid, but unusually large specimens usually bear two spines on a few of the plates proximally.

Perrier, in the article referred to, recognized fifteen genera in the family.

[1] Voyage Challenger, Zoöl., xxx, pp. 560-564, 1889.

[2] Expéd. Scientif. du Travailleur et du Talisman, Echinodermes, pp. 108, 109, 1894.

One of his diplacanthid genera (*Podasterias*) had *P. lütkeni* Per. (not *Asterias lütkenii* Stimpson) as its type, and is, therefore, of special interest in this connection. In a subsequent work [1] Perrier has added two more genera: *Distolasterias,* for *D. stichantha* (Sladen), separated from *Stolasterias* mainly on account of its two rows of adambulacral spines; and *Sclerasterias,* for *S. guernei* Per., a new and peculiar type. But in this later scheme he has judiciously omitted *Diplasterias* (Perrier, *non* Kœhler, *nec* Ludwig).

After a careful study of a large number of species, belonging to these various divisions, I am convinced that several other genera or subgenera, based on structural characters of quite as much importance, can be distinguished.

As understood in this work, the genus *Asterias* (type *A. rubens* L.) will be used in a sense much more restricted than by Sladen. I propose to keep separate, as genera, most of the groups called subgenera by Sladen—as, for example, *Cosmasterias, Smilasterias, Coscinasterias, Hydrasterias*—and most of the groups more recently proposed by Perrier.

Some of these generic groups need to be modified in definition or extent, and others should be added. (See below, under Geographical Distribution, for the characters of antarctic genera.)

I am well aware that many students of these starfishes do not think it worth while to subdivide *Asterias,* even to the extent that was done by Sladen and by Perrier. But in the case of so extensive a group, with a world-wide distribution, it will be practically impossible to intelligently study or discuss its evolution and distribution unless we recognize the relationship between allied species by means of distinctive group-names for minor groups, recognizable by morphological characters. We should aim at a phyllogenetic classification, and this is more likely to be attained by the recognition of morphologically similar groups of species than by an indiscriminate lumping of all these diverse forms in one great genus, containing perhaps two hundred species or more.

B. SUBDIVISIONS OF THE ASTERIINÆ HAVING DEFINITE LONGITUDINAL ROWS OF DORSAL PLATES AND SPINES.

Among the numerous species in which the dorsal plates and spines have a constant and characteristic arrangement, there are several divisions, apparently of generic and subgeneric value. Several of

[1] Contr. a l'étude des Stellérides de l'Atlantique Nord, Resultats des Campagnes Scientif., faits par Albert I, Prince de Monaco, fas. XI, pp. 34, 35, 1896.

these are not yet known from the northwestern coast, but are likely to occur hereafter, when more dredging shall have been done, and therefore it may be useful to give here a summary account of the principal groups of this kind.

Genus **Coscinasterias** Verrill.

Coscinasterias Verrill, Trans. Conn. Acad. Sci., 1, p. 248, 1867. (Type, *C. muricata* V. = (?) *C. calamaria* (Lam.).)

Stolasterias (*pars*) Sladen, Voyage Chall., vol. xxx, pp. 563, 583, 1889. (Type, *C. tenuispina.*) *Non* Perrier.

Coscinasterias and *Polyasterias* Perrier, Expéd. Trav. et Talisman, p. 108, 1894.

Body small, rays elongated, somewhat angular, usually carinate. Dorsal ossicles of the rays stout, four-lobed, usually arranged in three or five regular rows, besides the upper marginals, which form regular lateral rows. Actinal ossicles usually consist of one primary (peractinal) row, like the lower marginals, but they may be rudimentary and spineless in half-grown specimens, and only bear spines in large, mature individuals, as in *C. tenuispina.*

Minor pedicellariæ are abundant. Large forficulate or major pedicellariæ of the usual forms are present, often in considerable numbers, on the dorsal and lateral plates, and smaller ones occur on the marginal areas. Large unguiculate pedicellariæ are lacking. Adambulacral plates monacanthid or nearly so. Often autotomous; rays variable in number. Madreporites often two or more.

Stolasterias, which was proposed as a subgenus by Sladen in 1889, was nearly identical with *Coscinasterias,* characterized by me in 1867. He gave no reason for changing the name. It should be regarded as a synonym of the latter and be eliminated. Sladen's type was *A. tenuispina,* which is a *Coscinasterias* with the peractinal plates rudimentary and without spines, except in the larger specimens.

M. Perrier (1894) correctly retained *Coscinasterias* for the typical forms, like *calamaria,* but separated those species that are known to undergo spontaneous fission under the name of *Polyasterias* = typical *Stolasterias* Sla., though they do not appear to differ much in structure from the preceding, while he retained *Stolasterias* Sla., in a restricted sense, for those allied to *glacialis,* although C. *tenuispina* was named by Sladen as the type.

As *C. tenuispina* often divides spontaneously, it belongs to *Polyasterias* in Perrier's arrangement. This would make the latter strictly synonymous with Sladen's typical *Stolasterias,* which should

be restricted to this type as a subgenus, if retained at all. The group including *glacialis* had also been previously named *Marthasterias* by Jullien (Bull. Zool. Soc. France).

No species of typical *Coscinasterias* is known to me from the northwestern coast, but a species (*C. acutispina* Stimp., sp.), similar to *C. tenuispina*, and often having some diplacanthid adambulacral plates, occurs at Ousima Island, Japan. It is autotomous.

C. TABLE OF EXTRALIMITAL SPECIES OF COSCINASTERIAS AND CLOSELY ALLIED FORMS.

A. More than one distinct row of dorsal spines (usually three rows).

B. One row of peractinal spines and plates well developed. Rays variable, six to twelve. Mostly fissiparous.

C. Rays mostly seven to twelve. Adambulacral spines strictly uniserial (monacanthid). Lower marginals bear two spines each. Usually two or more madreporic plates are present.

C. muricata (VER.) 1867. (?=*C. calamaria.*) New Zealand

C. calamaria (LAM.). Australia; Indian Ocean.

C. jehennesii (PER.). Madagascar. (?=*calamaria*, teste Sladen.)

C. echinata (GRAY). Valparaiso. Rays eight.

C. gemmifera (PER.). Chile; Fiji Is. (?=*echinata.*)

C. (?)aster (GRAY). Rays twelve to thirteen. Five rows of dorsal spines (Gray).

CC. Some of the adambulacral plates diplacanthid. Rays variable.

C. acutispina (STIMP.). Ousima Island.

C. tenuispina LAM. (Large specimens.)

BB. No interactinal spines; peractinal plates rudimentary or lacking.

AA. Only one row of large dorsal plates and spines. Adambulacral plates monacanthid.

b. Rays mostly five to nine. Fissiparous. Subgenus *Stolasterias* (Sla. restr.).

C. (S.) tenuispina (LAM.) when young. Eastern Atlantic; Brazil; West Indies.

Variety *atlantica* (VER.). Bermuda; Cuba.

bb. Rays constantly five or six. Type not fissiparous.

Marthasterias (JUL.) when young. Type, *M. glacialis* (MÜLLER).

D. OBSERVATIONS ON VARIOUS GENERA.

Genus **Heterasterias** Verrill, nov.

Type, *Stolasterias volsellata* Sla., Philippines.

The rudimentary state of the dorsal skeleton and the lack of peractinal plates in the named species may entitle it to be considered the type of a new generic division, as suggested by Sladen. This view is strengthened by reason of the presence of large unguiculate dermal pedicellariæ. In this character and in general appear-

ance it resembles *Coronaster,* but the latter has only two rows of ambulacral feet. I would suggest *Heterasterias,* as a genus; type, *H. volsellata.*

Genus Marthasterias Jullien.

Marthasterias JULLIEN, Bull. Zool. Soc. France, p. 141, 1878.
Stolasterias (*pars*) SLADEN, Voy. Challenger, XXX, p. 563, 1889. Perrier, Voy. Trav. et Talism., pp. 108, 109; Résultats Camp. Scient., I, p. 34, 1896.

Rays five, angular, normally with three dorsal radial rows, besides the superomarginal rows, of stout plates bearing large, mostly conical spines; usually two on the superomarginals. Inferomarginal plates usually with two rows of spines. Adambulacral plates generally monacanthid, each plate with a single spine. Peractinal ossicles small and without spines, scarcely visible externally.[1] When young it has only one row of dorsal spines, the median, developed; when very large there may sometimes be more than three rows.

Besides the type, *M. glacialis* Müller, this group includes *M. africana,* of South Africa, and *M. rarispina* (Perrier).

The allied diplacanthid species were referred to another generic group (*Distolasterias*) by Perrier.

Genus Distolasterias Perrier.

Distolasterias PERRIER, Résultats des Camp. Scient., I, p. 34, 1896.

This name was proposed by Perrier for a group of which *Stolasterias stichantha* Sladen, of Japan, was the type. It is distinguished from his *Stolasterias=Marthasterias* by the diplacanthid arrangement of the adambulacral spines; and by having five or more regular close longitudinal rows of dorsal plates. The actinal plates are rudimentary and without spines.

But the *Stolasterias neglecta* of Perrier (1896, p. 37, pl. 1, figs. 2, 2*a*, 4-4*c*) is diplacanthid and therefore does not go in that genus, as he defines it, for in the same work (op. cit., p. 35) he makes the genus monacanthid. In this respect *neglecta* is like his *Distolasterias* (op. cit., p. 34), but the type of the latter has a much more complex dorsal skeleton, with five or more rows of dorsal plates and spines. *S. neglecta* apparently belongs with a group of which *A. forreri* Lor. may be taken as the type.

[1] For description and figures of skeleton, see Viguier, op. cit., pp. 100-105, pl. v, figs. 1-10, 1878.

Genus **Orthasterias** Verrill, nov.

Rays long, usually five, bearing three, five, or more dorsal rows of rather long spines, besides a superomarginal row on each side.

Inferomarginals bear each one or two spines, usually two. One row of interactinal or peractinal plates, with or without spines, close to the adambulacrals; the latter are diplacanthid; a short subactinal row may also occur rarely.

Lateral and dorsal dermal pedicellariæ are large, partly wedge-shaped or spatulate, often dentate, or unguiculate. Type, *O. columbiana* Ver., sp. nov. Also includes *O. dawsoni* Ver., nov.; *O. tanneri* Ver.; *O. biordinata* Ver.; *O. californica* Ver., etc.

Subgenus **Stylasterias** Verrill, nov.

Type, *S. forreri* Lor.

Dorsal plates in the adult usually in three regular rows, having elongated spines. Upper and lower marginal plates large and regular, with a well marked channel between, crossed by the large descending apophyses of the upper plates, and carrying papulæ and large forficiform pedicellariæ. Lower marginal plates close to the adambulacrals, each bearing one or two long spines. Peractinal plates lacking or rudimentary; when present never bearing spines, and so small as to be easily overlooked, without dissection. Adambulacral spines diplacanthid.

Among other species that belong to this group are the following:

S. enopla Ver., off Nova Scotia.
S. neglecta (Per.), East Atlantic.
S. contorta (Per.), West Indies.

Genus **Cosmasterias** Sladen, 1889.

This name was proposed for the group having as the first species, *Asterias* (*Cosmasterias*) *tomidata* Sladen (op. cit., pl. cv, figs. 8-10), and including also *Asterias sulcifera* Perrier, 1869 = *C. lurida* (Philippi), 1858.

Perrier has adopted *Cosmasterias* with *C. sulcifera*[1] (Per.), from off Patagonia, etc., as the type.

The genus is diplacanthid and has several regular rows of interactinal spines, but it has large, unguiculate or felipedal, dermal,

[1] For full synonymy and new descriptions of this species and *C. tomidata*, see Leipoldt, Asterioidea der Vettor Pisani Exped., 1895, pp. 552-563. See, also, below, under Geographical Distribution.

dorsal pedicellariæ, not found in northern polyactinoplacid types. Its principal dorsal plates are in regular radial rows.

This suggests an independent line of development, and hence the group may well receive a distinctive name. *C. tomidata* (Sla.), the type, was from Chile, in 45 fathoms.

Somewhat similar, large, unguiculate or felipedal pedicellariæ occur on *Stichaster polygrammus* Sla., off Patagonia; *S. felipes* Sla., South Africa; *Stolasterias volsellata* Sla., Philippines; *Coronaster briareus* (V.), Atlantic, and some other species.[1] In these they are not so sessile and rigidly erect as in *Pisaster*. Each of those species named is now referred to a distinct genus.

E. TABLE OF PRINCIPAL GENERA OF ASTERIINÆ WITH REGULAR LONGITUDINAL ROWS OF DORSAL PLATES AND SPINES.

I. NOT MORE THAN ONE ROW OF EVIDENT ACTINAL (PERACTINAL) PLATES,—MONACTINOPLACID OR ANACTINOPLACID.

A. Monacanthid, or nearly so.

B. Rays slender, variable, mostly six to eleven; often more than two madreporic plates when adult; usually autotomous.

C. One (often incomplete) row of actinal plates, closely united to adambulacrals, and usually bearing a simple row of spines (monactinoplacid). Major pedicellariæ large, compressed, ovate or pointed. Usually three or five rows of dorsal plates and spines.

a. Peractinal spines usually present in the adult.

Coscinasterias Ver. Type, *C. muricata* Ver.

aa. Peractinal spines mostly absent.

Section *Stolasterias* (Sla.), restr. Type, *C. (S.) tenuispina.*

CC. No visible actinal plates, the inferomarginals joining the adambulacrals (anactinoplacid). Only one row of dorsal plates—the median radials. Some large, unguiculate, dermal major pedicellariæ; some of the plates may be diplacanthid.

Heterasterias Ver., nov. Type, *H. volsellata* (Sla.)

BB. Rays five or six, stout. Three or five rows of strong dorsal plates and spines. No interactinal plates with spines. Usually but one madreporic plate; rarely two.

Marthasterias Jullien. Type, *M. glacialis* (Müll.).

AA. Adambulacral plates mostly diplacanthid.

D. No evident interactinal plates that bear spines; if present, rudimentary.

a. Five or more rows of stout dorsal plates and spines when adult. Major pedicellariæ not felipedal.

Distolasterias Per. Type, *D. stichantha* (Sla.).

[1] They often resemble, more or less, a pair of miniature clasped hands with fingers interlocked or two catspaws with claws protruded and interlocking, and hence they may be called felipedal. The name of *S. felipes* Sla. refers to this feature.

aa. Only three regular rows of dorsal plates with spines.
Stylasterias Ver., nov. Type, *S. forreri* (Lor.).
aaa. Usually only one row of dorsal plates (median) developed; they are broad, covered with a thick channeled dermis.
Sclerasterias Per. Type, *S. guernei* Per. E. Atlantic.
DD. One row of interactinal plates without or with spines (monactinoplacid). Three to five or more rows of dorsal plates and spines. Major pedicellariæ of two kinds. Some compressed, lanceolate or ovate; others large, thick, spatulate or wedge-shaped. Rays five or six.
Orthasterias Ver., nov. Type, *O. columbiana* Ver., nov.

II. TWO OR MORE ROWS OF ACTINAL PLATES AND SPINES (POLYACTINOPLACID).

A. Diplacanthid. Special large dermal pedicellariæ are unguiculate or felipedal.
a. Spines vesiculated.
Cosmasterias Sla. *C. tomidata* (Sla.).
aa. Spines not vesiculated.
Cosmasterias lurida (Phil.) = *sulcifera* Per.

F. SUBDIVISIONS OF ASTERIINÆ WITH RETICULATED DORSAL SKELETONS.

This large group presents fewer morphological characters for generic and subgeneric distinctions than the last, and some of them present gradations and intermediate conditions. However, if we separate the genus *Pisaster* and consider the large group to which *Asterias rubens, A. vulgaris,* and *A. forbesi* belong as typical *Asterias,* there will be left several more or less differentiated types of structure.

Genus **Leptasterias** Verrill.

Type, *L. mülleri* (Sars.).

This group, as separated by me, 1866, differs from true *Asterias* plainly in having only a few large papulæ in each cluster. Its typical species are *L. mülleri, L. compta, L. tenera,* etc. In these the dorsal spines are slender and numerous and the interactinal spines are in one row (rarely two). The discovery of numerous additional species, of larger size, and having more papulæ, now renders it difficult to make any sharp distinction, in this respect, between the two groups. Hence I have sometimes considered it as of only subgeneric value, and closely connected with typical *Asterias.* Its typical species carry the large eggs and young attached to the oral region, and the development is direct or abbreviated.

The most important generic feature is the fact that the genital pores are on the actinal side,[1] between the proximal inferomarginal plates, not dorsal, as in *Asterias*. The ovaries consist of comparatively few large digitate or glomerate tubules which, when filled with the large ova, appear beaded. The genital ducts are short and wide.

Genus **Evasterias** Verrill, nov.

Type, *E. troschelii* (Stimpson).

We may also distinguish this as a generic group, typified by *A. troschelii*. In this the dorsal plates and ossicles are small and reticulated, while there are three or more regular rows of stout interactinal spines and plates. The increased number of rows of interactinal plates and their closer union are the principal distinctions in this case, but the number of plates varies with age, so that the young specimens are essentially like *Asterias* in this respect.

Genus **Urasterias** Verrill.

Plate LXX, figures 1-4.

Type, *U. linckii* (Müller and Troschel.) = *A. stellionura* Perrier.

This type differs so much in structure from all others named that it should probably be considered a distinct genus.

The dorsal skeleton is very feebly developed, consisting mostly of small plates and delicate, short, rod-like or linear ossicles, united in an irregular network, with large meshes, but having a median radial row of rather larger, slightly lobed, spiniferous plates, and some similar lobed plates at the intersections of many of the meshes. The dorsal spines are slender, irregularly scattered, except the radials. Disk covered with a network of stouter, somewhat lobed ossicles, bearing solitary spines, and usually having in the type a larger flat plate, or group of such plates, at each interradial area, above, and extending to the lower side, and usually perforated by a pair of papular areas. This peculiar group of plates seems to be made up of a considerable number of plates in the adult, often united

[1] This is true also of the genus *Sporasterias* of southern South America and the Antarctic Ocean, including *S. antarctica* (Lütk.), the type = *Asterias rugispina* Stimp. = *A. spirabilis* Bell = *A. varia* (Philippi); *S. rupicola* Ver.; and several other nominal species; and probably, also, of *A. studeri* Per.; *Anasterias chirophora* Lud.; *A. belgicæ* Lud.; *A. perrieri* (Stud.); *Podasterias lütkeni* (Per.); *Stichaster nutrix* (Stud.), which carry their young in the same or a similar manner. They are all antarctic.

together in young specimens. Upper and lower marginal plates wide and strong, each bearing, in the young, a single spine. The upper marginal plates have a large and wide descending lobe; these join the stout upper lobe of the inferomarginals, but leave wide papular areas between them, along the wide lateral channels. The upper marginals have small side lobes, which are united together longitudinally, by smaller narrow, interpolated spineless plates.

Peractinal plates are small, or rudimentary without spines. The adambulacrals generally appear to be joined directly to the inferomarginals, but minute ossicles may intervene. Adambulacral plates diplacanthid or subdiplacanthid. (Pl. LXX, fig. 1.)

Major pedicellariæ are large and numerous, especially between the inferomarginal spines and on the inner margins of the grooves, but also occur on the back. They are acute-ovate and a little compressed. The minor pedicellariæ are unusually large and denticulate; they form very large pedicellate clusters, especially on the inferomarginal spines. Ambulacral pores and feet very large.

The lack of distinct peractinal plates and spines and the presence of the large interradial plates are very important morphological characters, aside from the feeble dorsal skeleton. The large size of the ambulacral pores is a notable feature.

The type, *U. linckii* = *stellionura* (Per.), is found from Spitzbergen to Nova Scotia.[1] Another arctic form, *U. gunneri* (Düb. and Kor.), is closely allied and may be only a variety (teste Ludwig). One or both of these may very likely be found hereafter in Bering Sea, for they are probably circumpolar.

Another arctic species, *U. panopla* (Stuxberg) seems to be congeneric with *U. linckii*. It has a similar, very feeble, reticulated dorsal skeleton, and lacks distinct peractinal plates and spines. Its proximal adambulacral plates in some cases bear three or four spines, but are mostly diplacanthid. The superomarginal and inferomarginal plates are cruciform and are connected by a narrow, spineless, intermediate plate. The inferomarginal ossicles usually bear two spines, sometimes more in large examples. It is from Spitzbergen, Barents Sea, Kara Sea, Finmark, etc. It is remarkable for the great number and large size of the dorsal minor pedicellariæ.

[1] It has been found as a fossil abundant in the postglacial clays at Salem, Massachusetts.

Genus **Parasterias** Verrill, nov.

Type, *P. albertensis* Verrill, British Columbia.

Five rays, stout; dorsal plates openly reticulated, much as in *Asterias;* interactinal spines and plates lacking; adambulacrals diplacanthid. For more details see below, p. 187.

Genus **Ctenasterias** Verrill, nov.

Type, *C. spitzbergensis* (Dan. and Koren).

Dorsal skeleton composed of an irregular network of slender, but numerous, mostly transverse ossicles, bearing large numbers of minute, uniform spines, arranged in transverse rows or combs on the sides of the rays. Marginal spines in two double rows near together. Adambulacral plates diplacanthid, or partly triplacanthid. Two forms of major pedicellariæ; the larger ones are lyrate or cylindrical and obtuse. A single row of small interactinal spines. Probably closely allied to *Leptasterias.* Reproduction not known.

C. cribaria (Stimpson) is pretty certainly identical with the type, which is from Spitzbergen.

Genus **Allasterias** Verrill.

Type, *A. rathbuni* (Verrill). Bering Sea.

Adambulacral spines alternately diplacanthid and triplacanthid, or monacanthid and diplacanthid; the inner spine of the larger alternate group is inserted on an angle of the plate within the edge of the furrow. Dorsal skeleton openly reticulated; superomarginal plates and spines form an angular margin.

Genus **Sporasterias** Perrier.

Type, *S. antarctica* (Lütk.) = *A. rugispina* Stimp. (teste Leipoldt).

Adambulacral spines regularly monacanthid. Dorsal skeleton irregularly reticulated, sometimes nearly as in some species of *Leptasterias,* sometimes weakly developed.[1] Genital pores ventral; the eggs and young are carried over and around the mouth, as in *Leptasterias.* For details, see below, under Geographical Distribution, p. 355.

Genus **Smilasterias** Sladen.

Type, *S. scalprifera* (Sladen). Off Patagonia, etc.

Adambulacral plates diplacanthid or triplacanthid, the spines and those of the inferomarginal plates large, flat, and placed in transverse rows. Dorsal skeleton irregularly reticulated with small spines.

[1] In *S. rupicola* Ver., from Kerguelen Island, the dorsal skeleton is well developed, with short, stout ossicles and numerous small spines.

Genus Meyenaster Verrill.

Type, *M. gelatinosus* (Meyen, 1834). Chile.

Meyenaster VERRILL, op. cit., 1913, p. 485.

Adambulacral plates monacanthid; one row of larger interactinal spines on thick ovate plates, each in line with two similar spines on each inferomarginal plate; superomarginal plates stout, each alternate one with a single large spine; a wide intermarginal lane bearing a regular row of papular areas, twice as many as superomarginal spines, and many large pedicellariæ. A row of median radial stout spines, usually one on each alternate plate; in large specimens an intermediate imperfect row on each side; medio-lateral skeleton reticulated irregularly with numerous short, transverse and oblique ossicles defining five or six irregular series of large papular areas on each side. Central part of disk symmetrically stellate with a central and twelve surrounding spines, in type. Large, stout pedicellariæ dorsal, lateral, and intra-ambulacral, compressed, ovate-triangular, not unguiculate; many very small acute, major pedicellariæ on papular areas; minor pedicellariæ abundant on large, broad, fleshy circumspinal sheaths. A thick, strongly canaliculated skin covers and conceals all the plates.

G. ANALYTICAL TABLE OF THE GENERIC AND SUBGENERIC GROUPS OF NORTHERN ASTERIINÆ HAVING RETICULATED DORSAL SKELETONS.

A. Monacanthid. Dorsal skeleton coarsely reticulate. Interactinal spines and ossicles well developed, in several rows. Large unguiculate erect pedicellariæ are present; rays five or six.
Pisaster (Ag.). Type, *P. ochraceus* (Brandt).

AA. Usually diplacanthid, or alternately diplacanthid and monacanthid, rarely triplacanthid. Interactinal plates and spines present or absent, or rudimentary.

B. Adambulacral spines confined to the outer or actinal surface of the plate.

C. Dorsal plates mostly angular or lobed. Interactinal plates and spines forming at least one row (peractinal), usually with other shorter proximal rows. Both rows of marginals well developed.
Asterias, sens ext.

D. Dorsolateral plates and transverse ossicles openly reticulated.

a. Interactinal plates strong, closely united, or imbricated in three or more rows in the adult, bearing several regular close rows of nearly uniform spines, like the inferomarginals; intervening papular areas small. Two kinds of major pedicellariæ usually present. Dorsal spines unequal, several on a plate, reticulate or areolate.
Genus *Evasterias* V. Type, *E. troschelii* (St.).

aa. Interactinal plates not so closely united; usually one or two rows, with larger papular areas between. Major pedicellariæ usually of but one kind. Dorsal spines rather irregularly arranged, usually scattered, sometimes areolate or acervate.

b. Papular areas large, bearing numerous small papulæ. Larvæ are usually free-swimming brachiolariæ; genital pores dorsal.

Asterias, restr. Type, *A. rubens* L.

bb. Papular areas smaller and bearing fewer large papulæ. Eggs and larvæ are usually carried by the mother around the mouth. No free larval stages; genital pores ventral.

Genus, *Leptasterias* Ver. Type, *L. mülleri* (Sars).

aaa. Interactinal plates lacking or rudimentary; papular areas large, numerous.

Parasterias, nov. Type, *P. albertensis* Ver., nov.

DD. Dorsolateral plates and ossicles wide, irregular, rather closely joined, leaving only small papular areas in longitudinal lines, but the ossicles do not form regular rows. All the dorsal and marginal plates are covered with close clusters of very small spines, longer on the inferomarginal and interactinal plates. Autotomous; rays mostly two or three to nine; finally six in adult.

Stephanasterias Ver. Type, *S. albula* (Stimp.). Circumpolar; North Atlantic; Bering Sea.

CC. Dorsal plates mostly rod-like. Interactinal plates small or rudimentary, mostly spineless. Usually two kinds of major pedicellariæ.

c. Dorsal skeleton feeble, composed mostly of small, linear or roundish, isolated and reticulated ossicles. Dorsal spines few and mostly scattered, but usually forming a median radial row. Both rows of marginal plates well developed and rather large, bearing single or double rows of stout spines, separated by a wide lateral channel. Dermal major pedicellariæ large and abundant, wedge-shaped. Minor pedicellariæ abundant on the spines and skin, attached to a large fleshy sheath on the spines. Alternate superomarginals without spines.

Urasterias Ver. Type, *U. linckii* (Müll. and Trosch.).

cc. Dorsal skeleton composed of nearly uniform short linear rods, irregularly reticulated, and covered with numerous small, uniform spinules, often in transverse rows or combs on the sides. Two rows of marginal plates near together, in the type bearing double rows of spines. Larger major pedicellariæ obtuse, large.

Ctenasterias Ver. nov. Type, *C. spitzbergensis* (D. and K.).

BB. The inner adambulacral spine, on alternate plates, is attached to the inner edge of the plate, or within the groove. Peractinal plates feebly developed or lacking. Dorsal spines small and numerous.

Allasterias Ver. Type, *A. rathbuni* V.

H. ASTERIIDÆ OF THE NORTHWESTERN COAST OF AMERICA.

This faunal region contains a remarkable assemblage of the representatives of this family. A few species from north of the Aleutian Islands are of arctic or circumpolar origin, but most are endemic. The most remarkable genus is *Pycnopodia,* strictly confined to this

region. The genus *Pisaster* is here represented by seven or eight large species, some of them being among the largest and most massive starfishes known. It is doubtful if the restricted genus occurs in any other fauna. The genus *Orthasterias,* with seven or eight species, is uncommon elsewhere. Its nearest allies are Atlantic species and *Distolasterias* of Japan.

A large proportion (fifteen) of the species of this region are normally six-rayed, which is a remarkable peculiarity.

Over twenty nominal species of Asteriinæ had been already described from the Northwest Coast, between southern California and the Arctic Ocean. In the collections studied by me there are about thirty additional species, besides twenty well-marked new varietal forms, or a total of about seventy.

Probably no other fauna is so rich in species of this group.[1] It is not improbable, however, that some of the supposed species may prove to be only local varieties, when larger series can be carefully studied. This may possibly prove true of some of the larger forms described by Stimpson, allied to *Pisaster ochraceus* and *P. capitatus,* but on the other hand there are probably many additional species to be found by dredging in moderate depths. Nearly all the known species of this region are littoral or very shallow-water forms. Deep-water species are not described in this report.

I. ANALYTICAL TABLE OF THE GENERA, SUBGENERA, SPECIES, SUBSPECIES AND VARIETIES OF ASTERIIDÆ FROM THE NORTHWEST COAST OF AMERICA.

1. Dorsal skeleton continuous, formed mostly of lobed plates and smaller ossicles overlapping at the ends; dorsal plates not isolated. Rays five or six, rarely more, unless autotomous.
2. Adambulacral spines all attached to the actinal face of the plates; none attached higher within the grooves.
3. Adambulacral spines in a single regular row, one to a plate, in the adult (monacanthid).

A. Interactinal plates present, at least in adults, and usually bearing spines.

C. Disk thick, rather large; rays five or six, stout, thick at base. Dorsal ossicles strong, numerous, not confined to three or five rows. Dorsal skeleton reticulate or irregular. Dorsal and lateral dermal major pedicellariæ sessile, large, stout, erect, ovoid or wedge-shaped, often nearly as thick as the spines, and usually strongly denticulated at the tips of the valves (unguiculate).

Genus *Pisaster* M. and Tr., p. 67. Type, *P. ochraceus* (Br.).

[1] The only other region that can be compared with this in the number and variety of Asteriinæ is the southern coast of South America, especially around Tierra del Fuego and Patagonia, whence numerous genera and species have been described, mostly very unlike the northern forms. (See below, p. 351.)

D. Interactinal ossicles numerous, stout, closely united in three to six longitudinal rows, usually bearing three to six or more close rows of strong actinal spines.

E. Dorsal spines arranged in a reticulate or areolate manner, or else grouped on the nodes; but often forming a median row on the rays. Rays normally five, stout.

a. Dorsal spines stout, coarse, very unequal, capitate, acervate, forming conspicuous angular reticulations with or without notable nodular groups and often with median radial rows.

P. ochraceus (Brandt), p. 68. Calif. to Middle Alaska.

a'. Dorsal spines mostly in very prominent nodes or clusters; reticulations less conspicuous.

Var. *nodiferus* V., nov., p. 71. Calif. to Alaska.

aa. Dorsal spines small, or rather small, acute or obtuse, not strongly capitate, usually forming evident reticulations.

b. Dorsal spines exceedingly numerous, very small, obtuse or acute, forming conspicuous reticulations, with or without radial rows and a central pentagon. Actinal spines stout, obtuse, but not strongly grooved externally.

P. confertus (Stimp.), p. 73. Calif. to Vancouver I.

bb. Dorsal spines small, slender, not very numerous, forming an openly reticulated pattern with a central pentagon and distinct median radial rows. Actinal spines deeply gouge-shaped and often bifid. Disk large.

P. fissipinus (Stimp.), p. 76. Oregon.

EE. Dorsal spines scattered, mostly without regular order, not reticulated, but sometimes forming radial rows. Rays usually stout, five or six.

d. Rays normally five. Dorsal spines large, with capitate or ovoid tips, not very numerous.

e. Dorsal spines few, large, nearly equal, obtuse or strongly capitate and radially striate. Rays short.

P. capitatus (Stimp.), p. 81. S. California.

ee. Dorsal spines more numerous, unequal, the tips ovoid or subconic and striated, usually forming imperfect radial rows. Rays long, rounded. Size large.

P. lütkenii (Stimp.), p. 83. S. Calif. to Vancouver I. Var. *australis* Ver., p. 88.

dd. Rays normally six; dorsal spines very numerous, short, stout, conical, acute or obtuse, striated, nearly uniformly scattered; no evident radial rows. Interactinal spines in four to six rows. Disk large. Size large.

P. giganteus (Stimp.), p. 89.

DD. Interactinal ossicles fewer, usually forming only two rows, and mostly bearing simple rows of spines. Dorsal ossicles openly reticulated. Dorsal spines few.

f. Rays normally five.

g. Dorsal spines rather sparse, short, thick, subconic, striated, scattered or clustered, with distinct median radial rows. Actinal spines short, obtuse, often flat, or slightly gouge-shaped at tip.

P. brevispinus (Stimp.), p. 77. S. Calif. to Vancouver I.

gg. Rays thick and high at base, rapidly tapered. Dorsal spines few, stout, blunt, or conical, mostly isolated, but forming imperfect median radial rows and a regular pentagon on the disk. Superomarginal spines one to a plate. Inferomarginal row double. Large dermal pedicellariæ numerous, stout, stone-hammer-shaped, with serrate jaws.

P. papulosus Ver., p. 91. Puget Sd., Brit. Columbia.

ff. Rays normally six, rarely five; more slender. Dorsal spines short, rather numerous, obtuse or capitate, irregularly arranged, often in groups of two or three. Interactinal spines in two or three rows. Major pedicellariæ acute-triangular.

P. grayi Ver. = katherinæ Per. (*non* Gray), p. 97. Oregon.

CC. Rays five; angular, more slender. Dorsal spines in three or five regular rows. Dorsal ossicles stout in longitudinal and transverse rows.

h. One or two rows of interactinal plates and spines. Major pedicellariæ large, ovate; minor pedicellariæ not very abundant. Superomarginal spines one to a plate.

P. paucispinus (Stimp.), p. 98. Calif. to Puget Sd.

AA. Dorsal spines in three regular rows, bearing dense subapical clusters of minor pedicellariæ. Superomarginal spines only on alternate plates. Ventral spines in two or three rows. Interactinal plates feebly developed.

Marthasterias sertulifera (Xantus), p. 100. Gulf of Calif. to S. Diego.

3'. Adambulacral spines two to a plate, arranged in two rows (diplacanthid); or else in irregular rows, when some of the plates have one and some two spines (subdiplacanthid).

B. At least one row of visible interactinal plates generally present in adults, often spineless; sometimes several close rows.

F. Dorsolateral plates rather small, narrow, strongly lobed, usually reticulated or irregularly arranged, and united by their own lobes and by smaller transverse ossicles.

G. Interactinal plates usually form one long row (peractinal), much like the lower marginals, and one or two short proximal rows (subactinals), but the latter may be mostly lacking or rudimentary, especially in the young, so that there may be only two simple rows of ventral spines; or the lower marginals and peractinal rows may be doubled proximally, two or more spines standing on each plate; thus the number of actual rows of these spines may sometimes be four or more. Dorsal ossicles variously arranged, most often openly reticulate. Major pedicellariæ usually small, ovate or lanceolate, sometimes unguiculate. Rays normally five or six.

H. Dorsal papular areas usually large; papulæ small and numerous, in groups of twelve to fifty or more, in the adult. Size generally rather large. Larva of many, if not all, species is a free-swimming *brachiolaria*. Genital pores dorsal.

Genus *Asterias* (L.), closely restricted, p. 101.

i. Rays normally five, ossicles and spines reticulate in arrangement.

j. Rays five, rather long, rounded. Primary dorsal spines few, short, stout (2 to 3 mm. thick), capitate, forming a median row, with few irregularly scattered ones of similar size and form. Two marginal and two interactinal, regular, mostly simple, rows of short, stout, blunt spines; adambulacrals subdiplacanthid.

A. victoriana Ver., p. 102. Vancouver I.

jj. Rays long, slender, acute; dorsal spines of moderate length, slender, fluted, mostly one to a plate, arranged in quincunx, or in about seven obscure alternating rows; median row with longer spines, distinct; both marginal rows single; peractinal row double, with spines longer than marginals; major pedicellariæ adambulacral, rather large, lanceolate.

A. namimensis Ver., p. 105. Brit. Columbia.

ii. Rays normally six.

k. Dorsal spines very diverse in form and size; primary ones very large, irregularly placed, but not acervate, very stout (2 to 4 mm.), with nipple-shaped, sulcated tips; smaller spines numerous, unequal, capitate or round-topped, with abundant minor pedicellariæ. Marginal and interactinal spines smaller, in about four close rows proximally; adambulacrals mostly two to a plate; the inner ones and furrow margins bear abundant clusters of small major pedicellariæ.

A. polythela Ver., p. 104. Arctic O. Jl 58, 70, 72, 94

kk. Primary dorsal spines not unusually large; not nipple-shaped.

l. Primary dorsal spines more or less unequal, capitate; the larger usually acervate or irregularly grouped. Pedicellariæ small, numerous; major ones ovate, forming clusters on the adambulacral spines, a few also on the interactinal areas. One complete row of peractinal spines, separated from the adambulacrals by a naked zone containing papular areas. Subactinal spines form a short series, or may be lacking.

A. acervata Stimp., p. 107. Bering Sea; Arctic O. Jl 27, 106

ll. Principal dorsal spines not very unequal nor distinctly acervate.

m. Dorsal spines rather small, irregularly reticulated; adambulacrals subdiplacanthid.

A. katherinæ Gray (*non* Per.), p. 112. Oregon; Gulf of Georgia.

mm. Dorsal spines very numerous, in distinst radial rows, not very diverse in size, capitate, several on a plate; the median row crowded and more or less clustered; both marginal rows double; two interactinal rows.

A. multiclava Ver., p. 114. Siberia. Jl 58, 59.

HH. Papular areas small; papulæ few, large, mostly standing singly or in small groups of one to five, rarely ten or more. Dorsal plates usually lobed and united by overlapping, sometimes in radial rows. Adambulacral spines alternately one or two to a plate, or else biserial. Minor pedicellariæ as in *Asterias;* large, serrate, dermal ones may occur. Eggs and young usually carried in clusters around the mouth of the mother; genital pores ventral. Size small. Rays normally five or six.

Genus *Leptasterias* Ver., in part, p. 116. (See below, p. 60.)

I. Rays normally five, sometimes varying individually to six.

n. Disk somewhat enlarged, thickened or depressed; rays not very slender; spines unequal and uneven; superomarginal row mostly single; inferomarginal row double.

o. Disk and rays depressed; dorsal spines very unequal; larger ones capitate, forming a prominent median radial row and irregularly linear groups; ventral spines all rather slender.

L. inequalis Ver., sp. nov., p. 117. Orca, Alaska.

oo. Disk thickened or plump; rays strongly convex; dorsal spines numerous, capitate or clavate, usually areolated, or arranged partly in clusters, often forming a median row; marginal and peractinal spines thickened.

L. epichlora (Br.), p. 132 (five-rayed form). Aleutian Is. to Puget Sd.

nn. Disk smaller, rays more slender or terete. Dorsal spines subequal, clustered, scattered, or somewhat in longitudinal rows.

p. Dorsal spines not remarkably small; not in transverse lateral combs. At least one row of interactinal spines proximally.

q. Rays very slender, terete; dorsal spines small, capitate, or clavate, numerous, mostly one or two to a plate, not in evident rows. Ventral spines slender, both marginal and peractinal rows single; major pedicellariæ large, with long spatulate blades.

L. leptalea Ver., sp. nov., p. 119. Virgin Bay, Alaska.

qq. Rays less slender. Dorsal spines small, clavate, in about three longitudinal rows, not crowded; both marginal rows regular and distinct, the spines longer and standing singly; interactinal row imperfect.

L. arctica (Murdoch), p. 120. Arctic O.; Bering Sea.

pp. Dorsal spines very slender, numerous irregularly arranged; superomarginal and inferomarginal spines longer, mostly one to a plate, in regular rows.

L. epichlora miliaris Ver., nov., p. 138 (five-rayed form). British Columbia.

ppp. Dorsal and marginal spines very numerous, small, subequal, arranged in close clusters, and largely concealed by the large dense wreaths of minor pedicellariæ; marginal plates of both series have two or three small spines, nearly concealed by pedicellariæ.

Leptasterias obtecta Ver., sp. nov., p. 144. Bering Sea.

nnn. Dorsal and dorso-marginal spines very small, numerous, nearly equal, the latter arranged in transverse lines on the narrow ossicles defining large transverse papular areas. Minor pedicellariæ small, around bases of spines, not unusually abundant.

Ctenasterias cribraria (Stimp.), p. 148. Circumpolar; Bering Sea; Arctic O.; North Atlantic.

II. Rays normally six, sometimes five or seven; not autotomous.

r. Disk small; rays slender, not enlarged at base; papulæ few, single or in small groups. Ambulacral pores of the usual size and form, more or less crowded, in four rows.

Genus *Leptasterias* Ver., in part, p. 116. (See above, p. 59.)

t. Dorsal spines small, slender, clavate, not crowded nor clustered, pretty regularly arranged in quincunx, surrounded by thick wreaths of

pedicellariæ; marginal spines longer; rows mostly simple; no peractinal spines.

L. coei Ver., sp. nov., p. 123. Off Berg Bay, Alaska.

tt. Dorsal spines longer, scattered; one or two to a plate, except in evident median radial row. Inferomarginal row double, two to a plate, longer than dorsals, subacute; superomarginal row simple; three interactinal rows proximally, one spine to a plate.

L. macouni Ver., sp. nov., p. 124. Vancouver I.

ttt. Dorsal spines mostly clustered, several on each plate.

u. Rays six or seven, elongated. Dorsal spines small, obtuse, arranged in five longitudinal ranges of groups, each group with three or four spines; others are on the transverse ossicles, so that they form "a vague reticulation." Ventral spines in two rows, pointed, longer than adambulacrals.

L. vancouveri (Per.), p. 125. Vancouver I.

uu. Dorsal spines small and numerous, all of about the same height, usually clavate, obtuse, standing in crowded rows. Marginal and interactinal spines notably longer, forming three to five or more close rows.

v. Dorsal spines small, slender, subequal, mostly clavate, not much crowded, standing singly or in small groups on the ossicles, forming median radial rows, and sometimes subradial series. Major pedicellariæ few, rather large, long, ovate.

L. hexactis (St.), p. 126. Calif. to Brit. Columbia.

vv. Dorsal spines mostly capitate, very small and very numerous, standing in large groups on each plate, about equal in height, and thus presenting a nearly even surface. Papular pores in nearly regular radial rows. Marginal and interactinal spines much longer, often bent, numerous, arranged in regular rows. Peroral spines strong.

L. æqualis (St.), p. 128. Calif. to Puget Sd.

w. Dorsal spines very short, equal, clavate or capitate, crowded, many on each plate. Marginal and interactinal spines form about four rows. Rays short, obtuse.

Var. *nana* Ver., nov., p. 132. California; Oregon; British Columbia.

ww. Dorsal spines very numerous and crowded on the plates, distinctly capitate, with rounded tips. Marginal and interactinal spines more numerous, forming five to eight rows, several on each plate.

Var. *compacta* Ver., nov., p. 130. California.

www. Dorsal spines very numerous, crowded, the clusters arranged in three or five radial bands separated by rows of very distinct papular areas.

Var. *concinna* Ver., nov., p. 132. California.

rr. Rays normally six, sometimes five, of moderate length, thick or wide at base, not slender, rather obtuse; disk somewhat wide or swollen, skeleton firm; principal dorsal ossicles rather large.

x. Dorsal ossicles not very closely united, irregularly reticulated, covered with numerous short, mostly capitate or clavate spines, usually reticulate in arrangement, often showing a more or less evident median row or band; three rows of interactinal spines often present proximally in adult, only one in small specimens. Adambulacral spines irregu-

larly diplacanthid, crowded; sucker-feet numerous, crowded in four rows. Large, denticulate, dermal major pedicellariæ often present in adult. Eggs and young carried by mother. Papulæ often in dorsal clusters of five to twelve or more.

L. epichlora (Br.), p. 132. Calif. to Aleutian Is.

a. Rays commonly five; dorsal spines very numerous, very unequal, strongly capitate, acervate. Median row not very evident.

Var. *subnodulosa* Ver., nov., p. 139. Wrangel, Alaska.

aa. Rays normally six.

b. Superomarginal spines stand two or three, or sometimes more, to a plate.

c. Dorsal spines quite unequal in size, mostly capitate; arrangement mostly areolated or reticulated.

d. Dorsal spines do not form a very evident median row, and are not notably acervate; reticulate arrangement conspicuous; larger ones capitate. Large denticulate dermal pedicellariæ often present, as well as the usual form; minor sort abundant.

Subspecies *alaskensis* Ver., nov., p. 136. Puget Sd. to Aleutian Is.

dd. Dorsal spines form an evident median row or band of larger spines.

e. Dorsal spines numerous, mostly clavate, not crowded, reticulate, with the median radial row very evident.

Var. *carinella* Ver., nov., p. 137. Alaska.

ee. Median radial dorsal spines decidedly larger, capitate, others small, crowded, reticulate and areolate.

Var. *siderea* Ver., nov., p. 137. Puget Sd. to Aleutian Is.

eee. Sometimes five-rayed. Dorsal spines crowded, very small, slender, clavate or slightly capitate; several small ones around each larger; median ones slightly larger; superomarginals unequal, one larger and several smaller on a plate.

Subspecies *miliaris* Ver., nov., p. 138. Alaska.

cc. Dorsal spines, mostly equal or subequal, short, capitate, numerous, crowded, areolate, often forming circles around the papular areas.

f. Dorsal spines are in five or more evident radial bands separated by rows of large papular areas, several spines standing on each of the larger ossicles, median band evident, but not prominent; three to four or more spines on each superomarginal plate; two on inferomarginals, stouter; one on peractinal, stout, clavate. Papular areas large. No large pedicellariæ on type.

Subspecies *plena* Ver., nov., p. 140. British Columbia.

ff. Dorsal spines very even, stout, capitate, crowdedly areolate, but not forming evident radial rows; median row irregular or obscure; papular areas conspicuous, but not in evident radial rows; mostly three spines on superomarginal plates; two on inferomarginals, all similar and near together, clavate, larger and longer than dorsals; peractinals similar. Large, erect, serrate major pedicellariæ common between marginal rows of spines.

Subspecies *pugetana* Ver., nov., p. 142. Puget Sd.

bb. Superomarginal spines mostly stand singly on the plates. A distinct dorsal median row.

g. Dorsal spines small, subequal, slender, clavate.
Var. *regularis* Ver., nov., p. 139. Alaska.

gg. Dorsal spines short, mammilliform, arranged somewhat in rows.
Var. *subregularis* Ver., nov., p. 139. Alaska.

xx. Dorsal and marginal ossicles stout, closely united, overlapping; median dorsal radial row prominent, bearing the larger capitate spines in a conspicuous irregular row; other spines of the larger sort form an irregular radial row on each side; inferomarginal spines longer and larger, two or three to a plate; single row of peractinals similar. Disk is rather wide, depressed.
L. dispar Ver., nov., p. 142. Aleutian Is.

GG. Interactinal and submarginal plates rather stout, lobate, closely joined in three to five regular longitudinal rows; each plate may bear one, two or more spines, forming, in the adult, four to eight or more rows of uniform or similar ventral spines. Rays five, rounded, usually long and tapered. Dorsal ossicles mostly reticulate. Papular areas large. Unguiculate dorsal pedicellariæ lacking.
Genus *Evasterias* Ver., nov., p. 151.

i. Rays five, gradually tapered. Dorsal spines numerous, unequal, areolate or reticulate, often clustered; larger ones short, capitate or truncate; smaller ones acute, capitate or clavate. Marginal spines in regular rows; longer than the dorsals; interactinal spines still longer, forming four to six or more regular close rows, curving strongly upward proximally; adoral spines elongated.
E. troschelii (St.), p. 151. Calif. to Alaska.

j. Dorsal spines acervate, or forming very evident nodular groups with larger central capitate spines, and often, also, a median row.
Var. *subnodosa* Ver., nov., p. 163. Puget Sd. to Alaska.

jj. Dorsal spines not acervate.

k. Dorsal spines smaller, very numerous, mostly clavate or subacute, few capitate, rough, openly reticulate; papular areas large; numerous crowded interactinal spines. Size large.
Var. *rudis* Ver., nov., p. 158. Vancouver I., etc.

kk. Dorsal spines nearly all capitate, not very unequal.

l. Dorsal spines nearly uniform, capitate, forming close reticulations, the spines in single lines on the ossicles.
Var. *densa* Ver., nov., p. 161. Vancouver I.

ll. Rays of moderate length, dorsal spines all capitate, reticulations coarse; both marginal rows of spines simple or nearly so, spines not crowded; two or three actinal rows, not crowded.
Var. *alveolata* Ver., nov., p. 162. Vancouver I. to Alaska.

kkk. Dorsal spines not very unequal, nearly all slender, clavate or subclavate, areolate, not acervate; marginals larger, subcapitate. Pedicellariæ numerous.
Var. *parvispina* Ver., nov., p. 163. Alaska.

ii. Rays five, long and large, acute at tips. Dorsal spines very numerous, small, unequal, the larger obtuse. The smaller ones are mostly acute and arranged in clusters and short transverse lines or combs, producing an imperfectly reticulate pattern, without distinct radial

rows. Interactinal and submarginal spines form five or six, mostly double, crowded rows, with about eight to ten in each transverse range, in the adult. Proximal adambulacral spines much elongated. Size large.

E. acanthostoma Ver., nov., p. 165. Alaska.

FF. The dorso-lateral spines, or groups of spinules, and more or less of the plates, have an evident arrangement in longitudinal rows. Interactinal plates present or rarely absent; seldom more than one row.

J. Dorsal plates strong, lobate, reticulated so as to form rather obvious longitudinal rows; papular areas usually large, often nearly rectangular. Each of the principal plates usually bears a single rather large spine, rarely two, forming three to five or more dorsal rows of spines; smaller spines may occur on the intermediate transverse ossicles. Marginal plates stout, bearing regular rows of spines, much like the dorsals. A row of similar peractinal plates, usually bearing a simple row of spines, often spineless, rarely lacking; sometimes a short row of subactinals proximally. Adambulacrals usually diplacanthid, sometimes subdiplacanthid. Major pedicellariæ large; usually of two or more kinds; the larger dermal ones denticulate, or unguiculate. Rays five or six.

Genus *Orthasterias* Ver., nov., p. 168. Type, *O. columbiana* Ver., sp. nov.

K. A row of interactinal plates is present, with or without spines; they may be small and not visible unless dermis be removed.

L. One row of peractinal spines, at least proximally; inferomarginals with two rows, making three ventral rows altogether.

a. Rays normally five, rarely six, elongated.

b. Dorsal spines in at least five rows, besides some intermediate scattered ones on the connective ossicles; papular areas rather small; dorsal radial plates rather large and thick, firmly united.

c. Five dorsal radial rows of spines obvious.

d. Apical oral spines not notably enlarged. Dorsal spines obtuse and fluted. Wreaths of minor pedicellariæ on thick dermal-sheaths, often above the middle of the spine.

e. Adambulacral spines flattened; adoral spines longer, not very slender; dorsal spines obtuse or truncate, rough or fluted.

O. columbiana Ver., sp. nov., p. 168. Vancouver I. to Yakutat, Alaska.

ee. Adambulacral spines all very slender and subequal; regularly diplacanthid, strongly and evenly divergent, thus forming two remarkably regular pectinate rows, those of the inner row usually horizontal.

O. biordinata Ver., nov., p. 173. British Columbia.

dd. Apical oral spines notably stronger than others. Dorsal spines tapered, not fluted. Minor pedicellariæ are notably minute, forming dense basal circumspinal wreaths. Major pedicellariæ are very large, stout, often as thick as spines, wedge-shaped, erect, often denticulate.

O. californica Ver., nov., p. 174. California.

cc. Longitudinal rows of spines more than five, not very obvious, due to crowding; spines appear as if in quincunx.

f. Dorsal spines long, slender, slightly grooved. Adambulacral spines slender, orals longer. Major pedicellariæ large, lanceolate, acute, dentate at tip.

O. kæhleri Lor., p. 175. Vancouver I.

bb. Dorsal spines in three rows, long, not fluted; ossicles openly reticulated, leaving large papular areas; spines of two inferomarginal rows and peractinal row slender, elongated, tapered; adambulacral spines rather slender, tapered or slightly flattened. Major pedicellariæ large.

O. dawsoni Ver., nov., p. 175. Brit. Columbia.

aa. Rays six, rounded and elongated. Dorsal spines large, in three or five rows, with smaller ones interpolated, all with a thick fleshy sheath (in alcohol) bearing a large wreath of minor pedicellariæ at about mid-height or above. Both marginal rows of spines are regular and mostly simple. A regular peractinal row of spines and in mature specimens a short subactinal row proximally.

O. merriami Ver., nov., p. 177. Alaska.

LL. Peractinal spines generally lacking; the ossicles are rudimentary or small; inferomarginals with two rows of spines.

Subgenus *Stylasterias* Ver., nov., p. 179.

g. Dorsal spines mostly in three longitudinal rows, often with some scattered intermediate ones.

h. Minor pedicellariæ remarkably large and unguiculate, about half as long as major ones, forming large, loose, basal circumspinal wreaths. Larger major pedicellariæ often nearly as stout as the spines.

i. Spines long, inferomarginals in two rows and, like the outer adambulacral spines, often notably flattened and spatulate or gouge-shaped. Outer adambulacral spines are the larger; papular areas large; peractinal plates very small.

O. forreri (Lor.), p. 179. California.

ii. Adambulacral plates and spines crowded; spines slender. Minor pedicellariæ remarkably large and abundant; dorsal ones in large groups on the dermis and around bases of spines; dorso-lateral ossicles rather slender, openly reticulated; papular areas large; major pedicellariæ very stout.

Subspecies *forcipulata* Ver., p. 180. British Columbia.

hh. Minor pedicellariæ not notably large; they form large, dense, basal circumspinal wreaths; inferomarginal and adambulacral spines flattened, not notably spatulate nor strongly gouge-shaped. Dorsal spines well spaced, elongated, tapered, not fluted; alternate superomarginal plates mostly spineless.

O. gonolena Ver., nov., p. 184. S. California to Gulf of Calif.

gg. Dorsal spines in more than three rows; rays slender, terete.

Dorsal spines in about five rows, long, nearly uniform, tapered; papular areas large; rays slender; inferomarginals tapered, obtuse; adambulacrals small, slender, outer ones a little larger and longer, slightly clavate. Major pedicellariæ large, denticulate.

O. leptolena Ver., nov., p. 182. British Columbia.

KK. No visible interactinal plates or spines. (See below, p. 66.)

Genus *Distolasterias* Per., in part, p. 185.

Dorsal spines numerous, in about seven to nine irregular alternating rows; rather short, fluted, blunt or clavate. Larger major pedicellariæ partly stout, wedge-shaped; partly elongated, spatulate, unguiculate, with few large curved teeth. Adambulacral spines slender, crowded, regularly diplacanthid.

D. chelifera Ver., nov., p. 185. Vancouver I.

JJ. Dorso-lateral plates mostly wide, lobed, overlapping or imbricated in few close rows (stichasterial arrangement), covered with clusters of minute spinules. A distinct peractinal row of plates. Disk small, rays slender, six in type. Ambulacral pores unusually large, subtriangular or cordate, not crowded. Dorsal spines very small, short, scattered, obtuse or clavate, a distinct median radial series.

Stenasterias macropora Ver., p. 145. Alaska.

BB. Interactinal plates lacking or rudimentary; no interactinal spines.

M. Dorsal skeleton weak, composed mostly of slender, openly reticulated ossicles, some of which do not unite in a continuous skeleton. Dorsal spines few, rather large, in few open rows or scattered; upper marginal spines regular and well separated from lower marginals; the latter with large and long spines; alternate plates without spines. Minor pedicellariæ large and very numerous, in sacculated wreaths or clusters. Size large.

Genus *Urasterias* Ver., p. 187. Type, *U. linckii* (M. and T.). Arctic; North Atlantic.

b. Several open rows of long dorsal spines; adambulacral plates not crowded; lower marginal spines large and well spaced; minor pedicellariæ not remarkably large; bunched in large wreaths on the large, loose, saccular sheaths of the spines. Size large.

U. linckii (M. and T.), p. 187 (extralimital?). N. Atlantic and Arctic.

MM. Dorsal skeleton well developed.

c. Dorso-lateral plates and ossicles openly reticulated. Rays regularly five, rather short, stout, depressed; dorsal spines numerous, small, slender, obtuse, arranged on small, slender, reticulated ossicles; no distinct median row; marginal spines usually two to a plate in both rows, in form like the dorsals, but rather longer; adambulacrals regularly diplacanthid. No interactinals visible.

Genus *Parasterias* nov., p. 187. Type, *P. albertensis* Ver. Brit. Columbia.

cc. Dorso-lateral spines and plates in more or less obvious longitudinal or transverse rows; spines either solitary or clustered.

d. Rays regularly five, large and long; dorsal plates bear large and mostly solitary spines and large pedicellariæ.

Genus *Distolasterias* Per., in part, p. 185. (See above, p. 65.)

dd. Rays slender, variable in number, due to autotomy; disk small; autotomous; finally six or five. Median and marginal plates little wider, imbricated in longitudinal rows; dorso-lateral ossicles and plates short, irregularly reticulated, but leaving regular rows of papular

areas. All the plates are covered with close clusters of small, nearly equal spinules, longer beneath. Pedicellariæ of two sorts; dermal, not abundant; few on spines.

Stephanasterias albula (St.), p. 147. Circumpolar; North Atlantic; Bering Sea.

2' The inner adambulacral spine, on alternate plates, is attached to a lobe of the inner edge of the plate, higher up within the groove. Dorsal spines small and numerous, scattered. Interactinal plates feebly developed or lacking.

Allasterias Ver., p. 188. Type, *A. rathbuni* Ver. Bering Sea.

f. Dorsal ossicles small, forming reticulations; adambulacral spines alternately two and three to a plate. Superomarginal spines clustered. Dermal major pedicellariæ large and numerous, pointed. Rays five, wide, depressed; margin prominent.

A. rathbuni Ver., p. 189. Bering Sea. See also, *A. forficulosa* V., nov., p. 194. Japan.

g. Inferomarginals not very stout, flattened, blunt, not deeply channeled.

Subspecies *nortonensis* Ver., p. 191. Bering Sea.

gg. Inferomarginal and actinal spines stout, channeled or gouge-shaped.

A. anomala Ver., p. 193. Siberia.

1'. Dorsal skeleton incomplete or rudimentary; ossicles partly isolated; dorsal surface covered by soft skin. Disk large; rays multiple, variable in number, increasing with age by interpolation in pairs up to twenty to twenty-four in the adult. Adambulacral spines monacanthid. Marginal plates distinct. Dorsal minor pedicellariæ in large clusters, dermal and epispinal.

Genus *Pycnopodia* Stimp., p. 197. Type, *P. helianthoides* (Br.), p. 198. Calif. to Aleutian Islands.

ASTERIINÆ: DESCRIPTIONS OF GENERA AND SPECIES.

Genus **Pisaster** A. Agassiz, ex Müller and Troschel.

Pisaster MÜLLER and TROSCHEL, Syst. Ast., p. 20, note, 1842. A. Agassiz, North American Starfishes, p. 96, 1877 (type, *ochraceus*).

Cosmasterias (*pars*) SLADEN, Voy. Challenger, XXX, p. 562, 1876.

Large starfishes with a thick and usually broad disk and either five or six stout tapering rays. Adambulacral spines form a single regular row, one to each plate (monacanthid). Three to six rows of closely united or tesselated, thick actinal and lower marginal plates, bearing several close rows of stout ventral spines. The synactinal plates are closely united to the adambulacrals. Oral region usually deeply sunken. Interbrachial septa well developed.

Special, very large, stout, erect, sessile, forficulate pedicellariæ, with interlocking serrations at the ends of the valves (unguiculate), stand on the lateral channels, and often between the actinal and dorsal spines; larger ones often stand in the interradial areas below.

Dorsal skeleton variable, but well developed, the ossicles generally

stout and openly reticulated. Dorsal spines few or many, and variously arranged, often in reticulate or acervate patterns, but sometimes scattered or in irregular rows.

One of the important structural features, characteristic of most of the species, is the increased number of rows of actinal plates and spines, and their close imbricated or tesselated arrangement; but in certain species (*P. papulosus*), otherwise related to the type, there are usually only two rows of actinal plates that bear spines below the inferomarginal plates, as in typical *Asterias;* very large specimens may have more rows.

But there is another character, perhaps, of more value, common to all the species from the Northwestern American Coast related to *P. lütkenii* and *P. ochraceus,* which seems to warrant the separation of this group, as a distinct genus. This is the existence of the peculiar form of large, stout, erect, sessile, dermal pedicellariæ, ovoid or wedge-shaped in form, with broad, unguiculate or denticulated, interlocking jaws. These occur especially along the naked spaces between the ventral and lateral spines, but they are also frequently found scattered between the dorsal spines, or between the bases of the actinal spines. They are often equal to the adjacent spines in diameter, but are much shorter. More slender, lanceolate or ovate, major pedicellariæ, of the ordinary type, always coëxist with these large forms, while the latter are not present on starfishes of the *Asterias rubens* type, nor on those belonging to most of the other divisions.[1]

It is probable, therefore, that this group had its origin upon the Pacific coast of North America, where it has subsequently had time enough to develop into many diverse species, some of which may have migrated to other regions and left descendants. This, then, is one of the most characteristic groups of this fauna, but it is not so strikingly peculiar as *Pycnopodia* and *Dermasterias.*

Mr. A. Agassiz (1877) referred to the name *Pisaster* as having been proposed by Professor L. Agassiz, for the group of species allied to *A. ochracea,* but he did not consider the group as more than a subdivision of *Asterias,* though he fully described the characteristic structures in the skeleton of *P. ochraceus,* as contrasted with a typical *Asterias.* Müller and Troschel had, however, proposed this

[1] A few similar large pedicellariæ often occur on *Leptasterias epichlora* (Br.), but not on the other allied species. They are often wanting, and may be due to hybridizing with *P. ochraceus,* associated with it. Similar large ones are found on *Orthasterias columbiana* and allied species.

name, for the same type, in 1842, but did not subsequently use it. This name should, therefore, take precedence of all others, whether it be considered a genus or a subgenus.

The mode of reproduction is unknown.

PISASTER OCHRACEUS (Brandt) A. Agassiz.

Plate XXI, figures 1, 2; plate XLIX, figures 3-3*d* (pedicellariæ); plate LVI, figures 3, 3*a* (variety).

Asterias ochracea BRANDT, Prod. Descr. Anim. Mertens, p. 69, 1835.

Asterias janthina BRANDT, op. cit., p. 69, 1835 (descr. insufficient; color var. ?).

Asterias ochracea STIMPSON, Journ. Boston Soc. Nat. Hist., VI, p. 87, pl. XXIII, fig. 2, 1867. Verrill, Trans. Conn. Acad. Sci., I, pp. 325, 326, 1867. Whiteaves, Trans. Royal Soc. Canada, IV, p. 116, 1887. A. Agassiz, North Amer. Starfishes, Mem. Mus. Comp. Zoöl., V, p. 96, pl. XI, figs. 1-7 (structure), 1877 (*Pisaster*). H. L. Clark, op. cit., 1907, p. 67, pl. VI, fig. 3 (structure). Loeb, Publ. Univ. Calif., Physiol., II, pp. 5-30, 1904 (hybridization).

Asteracanthion margaritifer MÜLLER and TROSCHEL, Syst., p. 20, 1842 (t. Bell).

Disk rather large, strongly reticulated by the prominent ossicles and spines; rays normally five, sometimes six, stout, rapidly tapered. Two Alaskan specimens, differing considerably in form, measure as follows: (a) lesser radius, 36 mm.; greater radius, 120 mm.; ratio, 1:3.33; (b) lesser radius, 32 mm.; greater radius, 118 mm.; ratio, 1:3.68.

The dorsal spines are numerous, unequal in size, but nearly all are capitate; the larger ones are short and stout, strongly capitate with flattened striated tops. They are arranged in short rows forming a conspicuously reticulated pattern, with large, deep, angular papular areas between them. They usually stand so closely in the rows that they nearly touch; on the disk they form a conspicuous pentagon, enclosing subordinate angular groups or partial reticulations and a central cluster. A zigzag, irregular median row is often distinct on the basal part of the rays. The smaller spines are similar in form but not so stout; they are partly grouped around the larger ones, and partly serve to subdivide the primary reticulations. Each primary papular area usually contains several large clusters of papulæ. Large, short, very stout, obtuse, wedge-shaped, unguiculate, dermal major pedicellariæ are more or less numerous on the dorsal surface, and still more so on the sides of the rays; they are rather less in diameter than the adjacent spines. Those in the lateral channels and interradial spaces are larger and stouter than the dorsal ones. Minor pedicellariæ form wreaths around the bases of the

dorsal and lateral spines and also occur in clusters on the papular areas.

The interactinal spines form four or five crowded rows; they are large, stout, mostly clavate, with obtuse, smaller, often flattened, striated or sulcated tips; those of the synactinal (inner) row are less stout, but not shorter; those of the interradial areas are longer and more fusiform. Toward the mouth the adambulacral rows of ossicles are prolonged as a narrow ridge to the sunken mouth, unaccompanied by actinal spines. The actinal spines bear clusters of minute minor pedicellariæ. The interactinal ossicles, as exposed in a denuded specimen, are small and closely arranged in about five rows at the base of the arm, with some additional ones irregularly interpolated. Large, pedicelled, lanceolate major pedicellariæ are attached within the margins of the furrows. The marginal spines are capitate and striated like the dorsal spines.

VARIATIONS.

In the Museum of Comparative Zoölogy I have seen two six-rayed specimens (No. 1423) from Crescent City, Calif. These have the dorsal spines unusually numerous, and strongly reticulated or areolated.

Two specimens sent to me by Mr. J. F. Whiteaves, of the Canadian Geological Survey, from Vancouver Island, are remarkable for their great size. They are 20 to 22 inches in diameter. Radii of one are 75 mm. and 250 to 275 mm.; ratios about 1 : 3.75. Radii of the other are 70 mm. and 240 to 260 mm.; ratios about 1 : 3.6. The disk is abnormally flattened in both, by imperfect preservation.

They agree with ordinary specimens in all essential features, except such as are naturally due to greater size. The dorsal spines are unequal and strongly clustered, but have lost more or less of their reticulated arrangement, except distally, owing to the breaking up of many of the lines of spines and the interpolation of new clusters. The spines and pedicellariæ are of the ordinary forms. The large, serrate pedicellariæ are very abundant on the dorsal, lateral, and actinal surfaces. The largest are on the actinal interradial areas, where some equal the spines in diameter.

Mr. Whiteaves also sent a short-rayed specimen, from the Queen Charlotte Islands, which has the dorsal spines larger, more capitate, and more numerous than usual, so that they form very prominent nodular clusters and imperfect reticulations. Its large unguiculate pedicellariæ are unusually abundant. (Var. *nodiferus*.)

In the same collection was a large six-rayed specimen from Discovery Sound, 1885, which differs in no other respect from the ordinary five-rayed specimen. A similar one, in our collection, was collected near Monterey, Calif., by Dr. W. R. Coe.

The smallest specimen that I have seen has the radii 14 mm. and 41 mm.; ratio about 1 : 2.8. The disk is elevated. The dorsal surface is thickly covered with characteristic nodular groups and imperfect reticulations of capitate spines, like those of larger specimens, but smaller. On the disk they form a distinct stellate pentagon and a central cluster.

The upper marginal row is simple. The inferomarginal row is double. There are also two simple rows of actinal spines; all these forming four very regular, close-set rows of nearly equal obtuse ventral spines. On the lateral channels, proximally, there are a few of the large, erect, wedge-shaped pedicellariæ, characteristic of the large specimens.

Its color is variable, and often very showy; most frequently it is dark or light orange, varying to yellow, to chocolate-brown, and to violet; spines are paler.

This is the most common of the species of *Pisaster,* from Monterey and San Francisco to Sitka. In most places it is by far the most abundant large starfish of the shores. It occurs at low tide among rocks and in shallow water.

It was collected by the Harriman Expedition at Sitka, Virgin Bay, Wrangel, and other localities in southern Alaska.

Mr. J. F. Whiteaves, of the Canadian Geological Survey, formerly sent me specimens from the following localities: Sooke, Vancouver Sound, one very large, 21 inches across (Macoun, 1887); Barclay Sound, one very large, 20 inches across (1887); Discovery Sound, one large six-rayed example, otherwise normal (G. M. Dawson, 1885); Queen Charlotte Islands (Dawson, 1885).

I have also examined many specimens from Victoria, B. C.; Puget Sound; Tomales Bay; Monterey; San Luis Obispo Bay; San Diego, Calif., and various other places on the coast of California. Its southern range extends certainly to Santa Barbara, Calif., and probably beyond San Diego.

This can scarcely be confounded with any other species, for its conspicuously acervate and reticulate, capitate dorsal spines are characteristic. The reticulation of *E. troschelii* and *L. epichlora* is much less conspicuous, and the former has more slender rays; but both, even when very young, differ in having biserial adambulacral spines. Larger specimens could hardly be mistaken.

PISASTER OCHRACEUS, Var. NODIFERUS Verrill, nov.

Plate LVI, figures 3, 3*a*.

This name is proposed for that variety of this species which has the dorsal spines collected into large detached groups.

The form is the same as in the typical reticulated variety, and specimens occur of all sizes from two inches up to a foot or more in diameter.

A strongly characterized small specimen from Monterey has the radii 16 mm. and 52 mm.; ratio, 1 : 3.25. The dorsal ossicles are reticulate, but so many are without spines that the latter show no regular reticulate pattern. The Geological Survey of Canada sent me several specimens with the nodular character even more prominent.

The dorsal spines are all capitate and somewhat unequal; they form a conspicuous pentagon with a central cluster on the disk and five prominent median radial rows proximally. Between the median and superomarginal rows there are ten to twelve large irregularly placed and very prominent clusters of capitate spines, with about five to eight spines in each group.

The superomarginal spines form a simple regular row in the type; they are about equal in size to the dorsal spines, but more conical. The ventral and adambulacral spines and the pedicellariæ are like those of the typical form. A very young specimen, also from Monterey, has the radii 8 mm. and 24 mm.; ratio, 1 : 3.

This small one agrees with the preceding in all essential characters, but the spines are correspondingly smaller and there are but two distinct rows of interactinal spines. The pentagon on the disk is well marked.

This variety occurs commonly from Monterey, Calif., north to Sitka, Alaska. It is the predominating variety on some parts of the coast of British Columbia, on rocks at low tide.

Six-rayed specimens are not very rare.

HYBRIDS ?

There are indications that this species may hybridize with *L. epichlora* and with others, for where they live associated, as at Sitka, specimens occur that seem to belong to *Leptasterias epichlora,* but have some of the characters of *ochraceus,* in a greater or less degree.

One young *L. epichlora* from Wrangel, Alaska (var. *subnodulosa*), has only five rays, and the dorsal spines are more strongly acervate and much larger than usual, giving it a close superficial

resemblance to the young of *ochraceus*, var. *nodiferus*, of similar size (diameter about 4 inches), but it has the biserial adambulacral spines and other characters of *epichlora*, and lacks the giant serrate pedicellariæ. (See under *L. epichlora*, var. *subnodulosa*.)

Other specimens have these variations in less degree, and many have more or less of the giant lateral pedicellariæ, which may indicate an infusion of *ochraceus* blood, so to speak, for they are not constantly present in *epichlora* and do not exist in the allied species.

Where so many closely related species are associated together, as on the Alaskan coasts, occasional hybridization is to be expected. It is well known to occur on certain middle portions of the New England coast, between *A. vulgaris* and *A. forbesi*, where the ranges of these two species overlap, as well as their breeding seasons, as at Wood's Hole and Vineyard Sound, Mass., just south of Cape Cod.

The *Asterias janthina* Brandt (Prod., p. 269, 1835), probably described from a colored drawing only, was so poorly characterized that no one has been able to identify it with certainty. Dr. Stimpson thought that it might be only a color-variety of *ochraceus*, and that is not unlikely, from Brandt's statement. His description was as follows:

"A species quite similar to the preceding (*ochraceus*) but different. Diameter of the disk less, rays a little longer, with more numerous and more crowded spines, much more numerous in the center of the disk, and not forming a pentagonal star. Back all light violaceus; spines white."

The relative length of the rays in *P. ochraceus* is quite variable, and so is the number and arrangement of the dorsal spines. Some of our Sitka and Vancouver Island specimens have the spines closely crowded. The color in most species of this group may vary between yellow, orange, red, and purple. This species is often violet or purple, in life.

PISASTER CONFERTUS (Stimpson).

Plate XXXVIII, figures 1, 2 (type); plate LIII, figure 2.

Asterias conferta STIMPSON, Proc. Boston Soc. Nat. History, VIII, p. 263, 1862. Verrill, Trans. Conn. Acad. Sci., I, p. 326, 1867. Perrier, Révision, p. 335 [71], 1875. Sladen, op. cit., p. 820. Bell. Proc. Zoöl. Soc. London, p. 494, 1881. Whiteaves, Trans. Royal Soc. Canada, IV, p. 116, 1887. De Loriol, Mém. Soc. Phys. et Hist. Nat., Genève, XXXII, part 2, p. 17, pl. III, figs. 1-1g, 1897.

Dr. Stimpson's original description was as follows:

"Rays five, stout, rounded, and dilated at base; disc large. Pro-

portion of smaller to greater diameter, 1 : 3.5. Ambulacral furrows broad at the base of the ray, where the pores are crowded into six rows. Ambulacral spines in one regular row, slender, compressed; subcylindric, as long as the ventral spines, somewhat tapering, with bluntly-rounded tips. Ventral spines crowded, very numerous, in six or seven rows near the base of the ray; short, subcylindric, a little bent outward, and slightly flattened externally, with more or less longitudinal striation near the tip. Beyond the ventral spines there are no regular channels, but the surface is covered with pedicellariæ and minute spines. The dorsal spines are numerous, equal in size, but very small,—not more than one-twentieth of an inch in length, scarcely capitate, but more or less pointed. They are uniformly distributed over the disc and rays in a reticulating manner, the interspaces being from one-tenth to one-half inch in diameter, and thickly crowded with groups of papulæ and minor pedicellariæ; the latter generally occurring about the bases of the spines, but not forming wreaths or crowns. The major pedicellariæ are very short and stout, regularly conical or somewhat wedge-shaped, with very broad valves. They are very numerous, particularly on the disc, where they often stand in groups of ten to twenty together. The largest are found isolated in the angles of the rays below, where one occurred having a diameter of eight-hundredths of an inch, and a regularly conical form, with a square base. Diameter of our only specimen, ten inches.

"It is allied to *A. ochracea*, but differs in its more numerous spines, pedicellariæ, and ambulacral pores.

"Habitat, Puget Sound—North West Boundary Commission. Dr. C. B. Kennerly."

I have reproduced large photographs of the type of this species, now in the National Museum. These were sent by Dr. R. Rathbun. (See pl. XXXVIII, figs. 1, 2, reduced.)

In this specimen the radii are about 45 mm. and 162 mm.; ratio, about as 1 : 3.6. The rays are thick at base and taper rapidly, though they differ considerably in this respect, indicating that the skeleton in life is rather flexible and weak. The crowded six-rowed or eight-rowed arrangement of the proximal ambulacral pores is very evident. The slender adambulacral spines near the mouth are much longer than those farther out, as in some other species; they stand singly on the plates, in one regular row. The ventral spines are pretty uniform in size and form, and are nearly smooth and blunt; they stand mostly in six rows proximally, but form only four or five rows at the

middle of the ray. Probably there are at least four rows of interactinal ossicles.

The dorsal spines, as stated, are small, mostly subacute, and arranged in a distinctly areolated or reticulated pattern, many of them forming regular transverse or oblique rows or combs on the reticulating ossicles; but they differ rather more in size than indicated in the original description, some of them being much smaller, more slender and very acute. But they are far more uniform than in *P. ochraceus*. They do not form a definite median row, The dermal minor pedicellariæ are numerous. The dorsal, sessile, dermal major pedicellariæ are often larger than the spines on the dorsal surface, especially at the interbrachial angles above, and also below, and along the lateral channels. The actinal spines bear thick clusters of minor pedicellariæ on their outer sides.

VARIATIONS.

A specimen of this species from Malaspina Inlet, coll. G. M. Dawson, 1885, received from the Geological Survey of Canada through J. F. Whiteaves, agrees well with the type in most respects, but it has distinct radial bands of small spines. Radii, 28 mm. and 110 mm.; ratio, 1:4; but the dried specimen is considerably flattened, due to imperfect preservation.

The dorsal surface is very irregularly reticulated; the numerous small spines have a tendency in many parts to form rather long transverse or oblique rows. Most of the spines are short and blunt, or subacute, but some of the smaller ones are slender and very acute. Minor pedicellariæ of very small sizes are exceedingly abundant, both in wreaths around the bases of the spines and on all the intermediate surface. The superomarginal spines form a somewhat irregular band of small spines, scarcely larger than the dorsals, several standing on each ossicle. The inferomarginal spines are similar, a trifle longer, blunt, and mostly striated distally, two often standing on one plate. The interactinal spines, which form three or four rows proximally, are similar in form, but increase in size toward the grooves. The adambulacral spines are long, slender, and regularly tapered. The giant pedicellariæ occur mostly on the interradial areas and lateral channels. Some of them are stouter than the interactinal spines, but shorter. They are usually stout and blunt, very obtusely conical or blunt wedge-shaped, with slightly denticulate tips. The ambulacral pores are crowded into eight rows proximally.

M. de Loriol (op. cit., 1896, p. 17, pl. III, figs. 1-1*g*) has described and figured a specimen, evidently of this species, from Vancouver Island. But his general figure (1) makes the dorsal reticulation much more regular than in the type, and the madreporic plate is put in the center of the disk, which is probably the fault of the artist.

I have received several other very similar specimens from near Victoria (C. F. Newcombe, coll.) and from Departure Bay (Geological Survey of Canada). None of these agree perfectly with the type.

This species is rare in collections and seems to be known only from Puget Sound, Vancouver Island, and British Columbia, where it is said to be common.

It is closely related to *P. ochraceus* and *P. fissipinus* by the character of the ventral and adambulacral spines, and by the reticulated dorsal surface. But the dorsal spinulation is even more like that of *E. acanthostoma* V. The latter has much longer rays, a much feebler skeleton, two rows of adambulacral spines, and lacks the very large, dentate, dermal pedicellariæ.

PISASTER FISSISPINUS (Stimpson).

Plate XXXIX, figures 1, 2 (type).

Asterias fissispina STIMPSON, Proc. Boston Soc. Nat. Hist., VIII, p. 264, 1862. Verrill, Trans. Conn. Acad. Sci., I, p. 326, 1867.

Pisaster fissispina VERRILL, Amer. Journ. Sci., XXVIII, p. 63, 1909.

Dr. Stimpson's original description is as follows:

"Five rays, short, and dilated at base; disc large. Proportion of the diameters, 1:3. Ambulacral pores near base of ray crowded, alternating, indistinctly six or eight rowed. Ambulacral spines in one regular row, as long as the ventrals, and flattened on the outer side. Ventral spines sub-equal, stout, sub-cylindrical, truncated, with fissured tips, and a deep, longitudinal sulcus on the outer side; they form five regular rows. The marginal dorsal spines are as large as the ventrals, capitate, with striated sides and pinched tips, and form an irregular row, of much fewer spines than occur in a ventral row. The spines of the back are few in number, and of only half the size of the ventral spines. They are shaped like the marginal spines, from which they are not ordinarily distinct, and are arranged on reticulating ridges, forming a rather open net-work. On the disc they form a pentagon, from each angle of which extends a median row reaching to one-third the length of the ray. Within the pentagon, close to its periphery, the madreporic plate is situated. The

dorsal spines increase in size toward the tips of the rays. Papulæ ing groups. Minor pedicellariæ nearly as in *A. ochracea* and *A. conferta;* major pedicellariæ smaller and far less numerous than in those species, but of similar short and stout form. Diameter, thirteen inches.

"Habitat Shoalwater Bay, Oregon Coast. Northern Pacific Railroad Expedition. Dr. J. G. Cooper."

Large photographs of the type of this species, which is still in the U. S. National Museum, were furnished by Dr. R. Rathbun. They indicate that the average radii are 60 mm. and 170 mm.; ratio, about as 1 : 2.83. The rays taper rapidly from a broad disk.

The slender adambulacral spines are compressed and much crowded, one to a plate. The peractinal and synactinal spines are mostly gouge-shaped, though often bifid at tip; but on the distal half of the ray, many are only sulcate and flattened. The dorsal surface was very accurately described by Dr. Stimpson, as may be seen by comparison with our figures of his type.

This species is more nearly allied to *P. ochraceus* than to any other. It differs in the peculiar gouge-shaped spines, in the more open reticulation of the dorsal skeleton, and in the much smaller and more slender dorsal spines.

The locality given by Stimpson is the only one positively known to me for this species.

PISASTER BREVISPINUS (Stimpson).

Plate XLI, figures 1, 2 (type); plate XLIV, figures 1, 2; plate XLV, figure 1; plate LXIX, figure 3; plate LXXVI, figures 1-1*b* (details).

Asterias brevispina STIMPSON, Journ. Boston Soc. Nat. Hist., VI, p. 88, pl. XXIII, fig. 3 (ventral spines), 1857.

Pisaster brevispina VERRILL, Amer. Journ. Sci., XXVIII, p. 63, 1909.

The original description by Dr. Stimpson is as follows:

"Rays five, each equalling in length twice the diameter of the disk. Upper surface covered with very short, blunt, nearly uniform spines, moderately numerous, sometimes forming an irregular row along the middle of the ray, and showing a tendency to reticulation on the sides. Beneath, there is a single row of slender ambulacral spines, which are blunt and somewhat irregular in length; between these and the marginal channel there are four rows of short compressed spines, gouge-shaped, or notched by an oblique concavity at their truncated extremities. Madreporic body large. Color yellowish. Diameter, six inches. Taken from a sandy bottom in ten fathoms near the mouth of San Francisco Bay."

Dr. Rathbun has sent nearly natural-size photographs of the original type of this species, which seems to be almost unknown in many later collections.

The disk is of rather large size and elevated; the five rays taper rapidly from rather wide and swollen bases. The radii are about 30 mm. and 116 mm., if the photographs are correctly marked as to reduction; ratio, about as 1 : 3.87.

The adambulacral spines are small and slender, mostly compressed, crowded in one row, one to a plate; those near the mouth are longer.

The inferomarginal and actinal spines are very much larger, rather short and very stout, mostly clavate or subspatulate, and with a deeply grooved or gouge-shaped tip; but many are simply sulcate and little flattened. They form four or five crowded rows near the bases of the rays, the inferomarginals bearing two spines, but at about the middle they are reduced to three or four regular rows. Most of them bear close clusters of minor pedicellariæ on their outer side. The superomarginal spines are smaller, fusiform or subconical, subacute; they form a pretty regular row, separated from the inferomarginals by a rather wide channel.

The dorsal spines are short, thick, nearly equal, with conical, mostly subacute tips. They are rather irregularly distributed, in short broken rows or singly; they form a somewhat evident median radial series, of two or three close irregularly alternating rows on the basal part of the rays; on the sides many of them are in obliquely transverse short rows, and sometimes short longitudinal rows can be traced. They bear small basal groups of minor pedicellariæ. Dermal minor pedicellariæ everywhere scattered between the spines. The sessile, dermal, major pedicellariæ appear to be few and mostly along the submarginal channel; they are rather small, short, subconic, obtuse. A few lanceolate, acute, major pedicellariæ occur along the edges of the ambulacral grooves.

VARIATIONS.

This species varies considerably in appearance, according to age, locality, and mode of preservation. When dried carefully, from alcohol, the disk is high and convex, while the mouth and jaws are deeply sunken; the rays are stout and high at base but rapidly tapered. There is usually a distinct median dorsal row of spines, simple in the younger specimens, but often double- or triple-ranked in the older ones.

On the medium-sized specimens the pentagon of the disk is very evident, but in large specimens it is obscured by the numerous interpolated scattered spines. In those about six to eight inches in diameter, the central plate, five radial, and five interradial primary plates are evident. Each bears a cluster, usually of four to six short, thick, clavate spines, with ovate or acorn-shaped striated tips. They are similar, in size and form, to those of the median radial rows.

Other somewhat smaller, but similar, spines are scattered within and around the primary pentagon, and over the dorsal surface generally. But the dorsal spines are not numerous in the young. They do not form distinct rows, but are irregularly scattered, and are mostly pretty nearly equal in size and form. In the larger specimen, ten to twelve inches in diameter, the dorsal spines become decidedly more numerous, and many are grouped two to four or more on one plate.

The superomarginal spines are similar to the dorsals, usually with rather more conical tips, which are strongly striated. They form a regular, close row, simple in the smaller specimens, but often double proximally in the larger ones.

The inferomarginal row is very regular and nearly always double, two spines standing obliquely on each plate, sometimes three in the larger specimens. They are rather stouter and more obtuse than the upper marginals, usually with the tips striated in small specimens; but in the larger ones these spines mostly lose their striations, and many become more or less flattened distally, while some are apt to have a distal furrow on the upper side ("gouge-shaped"), though this is by no means constant.

In nearly all the specimens there are but two simple, regular actinal rows of spines, making, with the inferomarginals, four close, unusually regular rows. The actinals are short and stout, similar to the inferomarginals. In the larger specimens some of them are somewhat flattened, and some are often grooved or slightly bilobed distally.

The adambulacral spines are slender, four or sometimes five corresponding to each synactinal plate. In young examples they are mostly regularly tapered and form a very regular even row; in the larger ones, many of them are often stouter, obtuse, cylindric, a little flattened, or even slightly clavate. They become longer proximally, near the mouth.

Major pedicellariæ of rather large size occur on the back, sides, and interradial axils, on the adambulacral spines, and on the inner

margins of the grooves. Those of the actinal side and ambulacral furrows are mostly acute-lanceolate or acuminate, compressed, with the sharp curved tips often overlapping. They often exceed the adambulacral spines in diameter. Those of the dorsal surface are shorter, stouter, ovate, with narrow obtuse tips, which are slightly denticulate. Those on the intermarginal furrow are largest and stoutest, with stronger denticulations.

Minor pedicellariæ are very small. They form small wreaths around most of the dorsal spines, and clusters on the outside of the ventral ones; small clusters also occur on the inside margin of the adambulacral plates and on some the larger major pedicellariæ. On the dorsal surface they form mostly rather small clusters, pretty evenly scattered over the whole surface; in large specimens they often become very numerous and pretty evenly distributed.

The papulæ are very small and apparently not very numerous, except in large examples. The integument is thick and firm, so that it conceals the outlines of the plates.

The mouth is deeply sunken. The jaws are elongated, narrow or much compressed, nearly perpendicular within; the adoral spines form two close rows of about eight each; the apical oral spines are rather stouter than the rest; there is often but one to a jaw.

The color, in the only case noted, was pale purple or pink.

A good specimen from off Monterey, Calif. (No. 1829*a*, M. C. Z.), differs somewhat from all the others. Radii, 33 mm. and 130 mm.; height in middle, 40 mm.

The central and ten primary radial and interradial plates are covered with clusters of short capitate spines with obtuse tips, about eight to ten in a cluster. About ten smaller plates within the pentagon are indicated by small clusters of simple spines. The median radial rows are conspicuous. On the proximal third of the rays they mostly contain three regular rows of spines; further out the three rows are less regular. On the distal fourth there is usually but one row. The other dorsal spines are mostly grouped in clusters of three to six, the clusters being irregularly scattered, largest on the sides of the rays. The spines are all similar, short, thick, with more or less conical, obtuse or ovate striated tips. The marginal and actinal rows of spines are very regular and even. They stand in close rows. There is a wide and deep intermarginal channel. The superomarginal row of spines is simple. The inferomarginal row is double. The two interactinal rows are simple and nearly equal.

MEASUREMENTS.

Serial number.	Radii: Lesser.	Radii: Greater.	Locality.
1304*a*	50 mm.	168 mm.	Off San Francisco.
1304*b*	26 mm.	73 mm.	Off San Francisco.
1304*c*	18 mm.	60 mm.	Off San Francisco.
1304*d*	42 mm.	110 mm.	Off San Francisco.
1821*b*	22 mm.	63 mm.	Off Santa Cruz, Calif.
1820*a*	33 mm.	130 mm.	Off Monterey, Calif.

This species ranges from south of San Francisco to Puget Sound and northward to Departure Bay, B. C. In the Museum of Comp. Zoölogy at Cambridge, Mass., I have studied a good series from off San Francisco (No. 1304); Crescent City, Calif. (No. 1303); Gulf of Georgia, A. Agassiz (No. 1301); Monterey Bay (No. 1820, see figs.); off Santa Cruz I., Calif. (No. 1821). It appears to be common in shallow water on the Californian coast. Very few authentic localities have been recorded hitherto, except that given by Dr. Stimpson (Bay of San Francisco). A single large specimen has been sent to me from Departure Bay, B. C. (coll. H. C. Young, Geological Survey of Canada).

PISASTER CAPITATUS (Stimpson).

Plate XXXVI, figures 3, 4 (type); plate LVI, figure 4.

Asterias capitata STIMPSON, Proc. Boston Soc. Nat. Hist., VIII, p. 264, 1862. Verrill, Trans. Conn. Acad. Sci., I, p. 327, 1867. ? Perrier, Arch. Zool. Expér., IV, p. 335, 1875 (six-rayed specimen, no descr.).

Dr. Stimpson described this species as follows:

"Rays five, not contracted at base; disc large. Proportion of diameters, 1 : 4.5. Ambulacral pores rather narrow, in four regular rows. Ambulacral [adambulacral] spines in one regular row, linear, compressed, and blunt. Ventral spines as long as the ambulacrals, capitate, with bluntly-rounded heads, elegantly striated on the convex inner face and tip, and with a median sulcus on the outer side. They are arranged in four rows, those of the outer row being largest; and there are some minor pedicellariæ on the outer sides of the spines in all of the rows. The dorsal spines are not very numerous, but are for the most part large, their regularly globular and beautifully striated or radiated heads being about eight-hundredths of an inch in diameter, and larger than those of the ventral spines. They are arranged without order, standing about one-seventh of an inch apart; but five or six longitudinal rows may be obscurely traced, the marginal row being most distinct, containing eighteen or twenty

spines. On the disc, there is a central tubercle, but scarce any indications of a pentagon. Around the bases of the dorsal spines there are regular wreaths of minor pedicellariæ. The major pedicellariæ, which are of the short, conical or sub-globular form, with broad valves, are scattered between the spines as in *A. ochracea.* Papulæ in groups.

"Color in life purple, according to Dr. Newberry. The spines are probably white, or at least of a lighter color. Diameter, five and a half inches.

"This very pretty species differs from *A. ochracea* in its larger dorsal spines, which are not arranged in a reticulating pattern; and from *A. Lütkenii* in its shorter and more numerous ventral spines, as well as in the presence of major pedicellariæ on the back.

"Habitat, San Diego, Cal. Colorado Expedition. Dr. J. S. Newberry."

The photographs of the type, sent by Dr. R. Rathbun, are six inches in longest diameter; radii, 18 mm. and 80 mm.; ratio, nearly 1:4.5.

Little need be added to Stimpson's description of the type. The adambulacral spines are often flattened. The ventral spines are unequal; those of the inner or synactinal row are distinctly smaller than the others, and the outer or peractinal are largest. Most of these spines are stout and clavate, rather than capitate, the tips being mostly obtusely conical or ovoid and strongly striated; only a part are grooved; distally they become much more slender and distinctly clavate.

The superomarginal spines are considerably stouter than the ventral ones, but not much longer. They form a regular simple row of rather widely spaced spines, each one on the raised node of a marginal ossicle. The dorsal spines are mostly quite similar to the laterals in size and form. The larger ones have large, rounded, capitate, and strongly striate tops; but those toward the ends of the rays become longer and more slender, cylindrical or clavate, rather than capitate, but striated in the same way.

The spines are distantly spaced, generally one on each raised node of the reticulating ossicles. Usually, in our specimens, five or six ridges, indicating the lobes of the ossicles, radiate out from the base of each spine, so that the skeleton has a pretty regularly reticulated structure. The spines usually form more or less evident median, radial rows, and sometimes two less distinct rows can be traced, between the median and marginal rows.

In the Museum of Yale University there is a specimen of this species collected at Monterey, Calif., which agrees very closely with the type in size and structure.

The radii are 20 mm. and 70 mm.; ratio, 1 : 3.5. The rays are shorter than in the type. The spinulation agrees in all essential points with the type, though the distal dorsal spines of the rays appear longer and less stout, and more of them have the clavate form.

The wreaths of minor pedicellariæ about the spines are not conspicuous, but they contain very large numbers of very minute pedicellariæ. Others of similar small size are scattered between the spines or grouped in dermal clusters on or around the large papular areas. The papulæ are small and form large groups, above and below.

The dorsal and lateral dermal major pedicellariæ are moderately large and stout, ovoid or subconic, with obtuse and usually denticulated jaws. They are not nearly so numerous nor so large as in the type. Most of the actinal spines are clavate and many lack the sulcus on the outside; the synactinal spines are smaller and more cylindrical; between them are large papular areas. The dorsal skeleton is firm and distinctly reticulated, with a tendency to a six-rayed arrangement around the principal spines, which are not so numerous as in the type.

Monterey, Calif. (R. E. C. Stearns, Mus. Yale Univ.); San Diego (Stimpson, Ives, and others); San Diego (Mus. Yale Univ. coll.).

This species is closely allied to *P. lütkenii.* It differs especially in having much fewer dorsal spines, which are also larger and more distinctly capitate. The ventral (actinal) spines are more unequal, stouter, shorter, and more capitate.

PISASTER LÜTKENII (Stimpson).

Plate XL, figures 1, 2 (type).

Asterias lütkenii STIMPSON, Proc. Boston Soc. Nat. Hist., VIII, p. 265, 1862. Verrill, op. cit., 1867, p. 32. Perrier, Révis., p. 70, 1875. Bell, Genus Asterias, Proc. Zoöl. Soc. London, 1881, p. 495. Sladen, op. cit., pp. 566, 824, 1889. De Loriol, Mém. Soc. Phys. et Hist. Nat., Gèneve, XXXII, p. 15, pl. II [XVII], figs. 1-1*h*, 1897 (description).

Pisaster lütkenii VERRILL, op. cit., p. 63, 1909.

Asterias exquiseta DE LORIOL, Rev. Zool. Suisse, 1888, p. 463, pl. XVIII, fig. 2 (young).

When full-grown this is one of the largest starfishes on the coast. Dr. Stimpson's type was not half-grown. The following is his description:

"Rays five, rather broad, with blunt tips; disc moderately large. Proportion of the diameters, 1:4.25. Ambulacral pores in four regular rows. Ambulacral [adambulacral] spines in one regular row, slender, long (but not longer than the ventrals), not compressed, but tapering to a blunt point. Ventral spines in four approximated rows, elongated, scarcely capitate; heads elongated, subtruncate, striated within, and often sulcated along the middle on the outer side, where there are always semicircular clusters of minor pedicellariæ. Beyond the ventral spines there are distinct lateral channels. The dorsal spines are uniform in size and distance, being about one-fourth of an inch apart in one specimen, and arranged without order, except in the regular marginal row, which consists of about thirty spines; and they form no pentagon on the disc. They are one-eighth inch high, and half that in breadth, capitate, with the heads striated and conical, with pinched tips. Around the base of each there is a rather narrow ring of minor pedicellariæ. There are no major pedicellariæ scattered among the dorsal spines, but a few occur in the lateral channels, similar to those of *A. ochracea* and *capitata,* but of smaller size and with narrower valves. Papulæ in groups. Diameter, one foot. It differs from *A. gigantea* in having only five rays, and in other particulars.

"Habitat, Coast of Oregon. Mus. Smithsonian."

Photographs of the types of this species were also kindly sent by Dr. R. Rathbun from the U. S. National Museum. As marked, the photographs give the radii as 24 mm. and 96 mm.; ratio, 1:4.

The description by Dr. Stimpson is so good, in this case, that little need be added to it. The upper marginal spines form a pretty regular row; they are about as large as the ventrals, but more conical, and like the dorsal spines in form, though rather larger. The median dorsal row of spines is not often very evident; in some places indications of four or five other longitudinal rows can be seen on either side, so that there may be ten to twelve spines in a very irregular transverse series, but there are no distinct transverse rows. On the distal part of the rays the wreaths of minor pedicellariæ, around the spines, become larger and crowded; there are also large clusters of dermal minor pedicellariæ scattered over the whole dorsal surface, many of them on the papular areas, besides many single pedicellariæ.

Two very large and perfect specimens of this species are in the Museum of Yale University, collected at Pacific Grove, California, by Professor W. R. Coe, 1901.

One of these (*a*) agrees very closely with the type, except in features due to its much greater size. Its radii are 60 mm. and 270 mm.; ratio, 1 : 4.5.

The dorsal surface is nearly uniformly covered with conical spines, not forming definite rows. About twenty-one to twenty-five may be counted in an irregular transverse series at the base of the rays.

The upper marginal plates mostly bear two spines at the base of the rays, but only one distally. The lower marginals bear two complete rows, to the tips of the rays.

There are three regular rows of actinal spines proximally, mostly one to a plate; the first is complete to the tips; the second ceases near the tip; the third at about the distal third.

The inferomarginal row and first two actinals are all close together and much alike; they are rather short, very stout, clavate, with rounded, striate tips, channeled on the outer side. The synactinal spines are longer and not quite so stout, tapered and channeled on the outer side. On the interradial areas some of the actinal spines are also longer, conical, and subacute.

The adambulacral spines are slender and tapered, becoming decidedly longer toward the mouth and on the adoral plates. The adoral carinæ are about 14 mm. long, strongly compressed, and consist of about eleven or twelve closely united pairs of adambulacral plates, sloping upward, and normally bearing each one long spine; but in many cases one is lacking in a pair, and on some of the carinæ two to four pairs are destitute of spines. Those in the last erect pair (epiorals) on the jaw are longer and stouter than the others. The terminal or peroral pairs of spines are horizontal, short, stout, flattened, enlarged or subspatulate at the blunt tips. A short, thick, strongly lateral divergent spine, not half as long, occupies the side angles.

The adambulacral pores are large, and on the proximal part of the rays, within the radius of the disk, they form eight distinct rows; they are reduced to four regular rows a little beyond the border of the disk. On about three adoral pairs of plates, they also decrease, the innermost being a single pair.

The minor pedicellariæ are abundant on nearly all the spines, but the wreaths around the bases of the dorsal and marginal spines are not so large as in var. *australis*. Numerous, large, erect, sessile, stout-ovoid and stone-hammer-shaped pedicellariæ, with strongly serrate, blunt jaws, are scattered everywhere over the back, on the

lateral channels and among the ventral spines. Along the inner edges of the adambulacral grooves, attached by pedicels, there are many compressed and longer ones, some of which are larger than the dorsals, others much smaller. These are mostly long-ovate, often with incurved margins and blunt at the tips, which are dentate; others are acute-lanceolate, and many are quite small.

In the Museum of Yale University there are also several smaller dry specimens of this species, agreeing very closely with the type.

The best medium-sized specimens, with the radii 40 mm. and 180 mm., have the ratio as 1 : 4.5. The adambulacral spines are slender, terete, subacute, arranged in one simple row. Those near the mouth are not much lengthened; more distally many of them are somewhat flattened, with obtuse or slightly spatulate tips. They are mostly without minor pedicellariæ, though small groups occur on some of them. A few bear single, rather large, ovate-lanceolate major pedicellariæ, like the adambulacral pedicellariæ. The latter are rather numerous, attached to the inner edge of the adambulacral plates, at or within the margin, by a long pedicel, which often bears a cluster of minute acute pedicellariæ at and below the base of the large one; the latter is unusually large, compressed-ovoid, subacute or obtuse, with the tips of the jaws often denticulate. Their pedicels are often as long as the adambulacral spines. The actinal spines are large, subequal, and form four or five regular rows, proximally, but usually only four beyond the middle of the ray; they become much more slender distally; those of the interbrachial region become longer, fusiform, and often acute. Most of them are stout, clavate or subcapitate, strongly sulcated on the outside and with the tip finely striated all around. Most of them bear a small cluster of minor pedicellariæ on the outside. There are, apparently, only four rows of peractinal and synactinal plates. The outer (peractinal) ones often bear two spines.

The marginal spines are larger and rather longer, similar to the dorsal spines, and with subconic striated tips; they form a very regular row, standing singly and well spaced on a row of somewhat raised ossicles, and leave below them a wide and well defined marginal channel, which becomes dilated at the interbrachial region.

The dorsal spines are similar in form but unequal in size, numerous, arranged without any very evident order, but pretty evenly spaced. They mostly stand singly on the nodes of the reticulating ossicles, which form five to seven radial ranges and nine to ten in transverse series. The dorsal spines bear a thin basal wreath of

minor pedicellariæ. There are also many small clusters of dermal minor pedicellariæ. Papulæ small, very numerous, in clusters.

The dorsal major pedicellariæ are numerous, scattered among the spines and especially in the lateral channels. They are short, thick, ovoid, obtuse, with the jaws denticulated at the apex; they often equal the smaller spines in diameter, but are shorter.

This species can only be confounded with *P. capitatus,* to which it is evidently closely allied. The latter, however, not only has much larger and more capitate dorsal spines, but they are much fewer in number, there being usually only about five or six spines in a transverse series, besides the laterals.

The supposed absence of large major pedicellariæ on the back of *P. lütkenii,* referred to by Stimpson, does not hold good, as shown by our specimens, above described.

This species appears to range, in its typical form, from Vancouver Island to Monterey, California, and as a variety farther south to San Diego.

Oregon (Stimpson); Saanich Inlet, Vancouver Island (de Loriol); San Diego and Monterey, California (Yale Museum); Vancouver Island (Canadian Geological Survey); off Pacific Grove, near Monterey, taken on fish lines (Dr. W. R. Coe. Two very large specimens, *a, b*).

When full-grown this is one of the largest starfishes on the Northwest Coast. It is equalled, in this genus, only by *P. achraceus, P. giganteus,* and *P. papulosus.*

VARIATIONS.

One of the very large specimens (*b*) obtained from off Monterey by Dr. Coe, 1901, differs considerably from the more typical ones in the character of its spinulation, due perhaps, to a superabundance of food.

Its radii are 55 mm. and 284 mm.; ratio, about 1:5.2. It is noticeable on account of the great development of its actinal and inferomarginal spines, which are decidedly more numerous and longer than in the other specimen of equal size and from the same place, described above.

The proximal inferomarginal and most of the actinal plates bear two, three, or even more, stout, often divergent spines, so that one can count eight to ten of these spines in each irregular transverse series. But one ray (doubtless a reproduced one) is only about two-thirds as long as the rest, though nearly as stout; on this the ventral

spines form only four or five rows, though similar in size. On the distal half of all the rays the ventral rows decrease to about four to six, the plates bearing only two spines, or but one.

The ventral spines are unusually crowded proximally. They are also longer and less stout, though mostly blunt, except the synactinals and those on and near the interradial areas, where many of them become decidedly longer and acute. Many in the synactinal row are deeply grooved on the outside, and the distal ones become more slender and subacute. The adoral spines are long, slender and acute.

Large serrate major pedicellariæ are scattered over the dorsal and lateral surfaces, but are not half so numerous as on the other large specimen.

The dorsal spines are less numerous, larger, more acute, and more regularly spaced, their average intervals being 8 mm. to 10 mm. wide.

Minor pedicellariæ form dense wreaths around all the dorsal and upper marginal spines.

Off Pacific Grove, California (Dr. W. R. Coe, 1901).

PISASTER LÜTKENII Var. AUSTRALIS Verrill, nov.

Two very large specimens (*c, d*) of this variety are in the Museum of Yale University. One has the radii 56 mm. and 252 mm.; ratio, 1 : 4.5.

The oral adambulacral spines are one-fourth longer than those of the mid-ray; they are long, slender, regularly tapered. The ventral spines, near the base of the rays, are in four and five crowded rows; but on the mid-ray there are about four regular rows; those of the inner and middle rows are very stout and blunt, often nearly as thick as long, irregular in form, often pinched, lobed, or sulcated, and sometimes slightly bifid; the tips are often clavate, swollen, or truncate.

The inferomarginals, or two outer rows, and those near the mouth, are longer, not so stout, and more regular, mostly with obtuse or ovoid tips. Distally they become longer and more fusiform, and many are deeply channeled on the outer side.

The inferomarginal spines stand two on a plate, nearly or quite to the tips of the rays, and thus form the two outer rows of ventral spines. There are proximally three rows of stout actinal plates, each usually bearing a single spine, thus forming three rows; the first row (peractinal) extends to the tip of the ray; the third row (synactinal) only extends to about the distal third of the ray.

The dorsal spines are much less numerous than in the typical variety; they are evenly scattered, and scarcely form any distinct radial rows. About thirteen to fifteen spines occur in irregular transverse series, besides the upper marginals, but they do not form any definite transverse rows.

The upper marginals are much like the dorsals, but larger. They mostly stand singly on the large plates, so that they are well apart.

Between the upper and lower marginals there is a rather wide, naked channel, bearing large pedicellariæ; at the base of the rays it expands into a rather large, triangular, interradial area, destitute of spines.

Minor pedicellariæ, in very large dense wreaths, surround the upper marginal and dorsal spines, the clusters becoming so large distally that they are in contact. In dry specimens they seem to be attached outside the swollen base of the spines, which is covered by a thick skin, but in life they probably rise up at least to mid-height of the spine. On the ventral spines they form large clusters on the outer surface.

Very large, ovoid, or blunt stone-hammer-shaped, erect, sessile, major pedicellariæ, with strongly serrate jaws, occur in considerable numbers on the lateral channels, between the dorsal spines, and among the ventral spines. Other major pedicellariæ, some of them nearly as large, but others much smaller, somewhat compressed, mostly ovate and obtuse, occur on the adambulacral spines and on the inner edge of the ambulacral grooves. Many of these have large numbers of small, acute, forficulate pedicellariæ on their pedicels.

San Diego, California (Dr. Edw. Palmer, Yale Museum). 4029

PISASTER GIGANTEUS (Stimpson) Verrill.

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Plate XXXVII, figures 1, 2 (type).

Asterias gigantea STIMPSON, Jour. Boston Soc. Nat. Hist., VI, p. 88, pl. XXIII, figs. 4-6, 1857. Verrill, Trans. Conn. Acad., I, p. 327, 1867. ? Bell (*pars*), Proc. Zoöl. Soc. London, 1881, p. 564; = in part *A. katherinæ* Per., *non* Gray.

Dr. Stimpson's incomplete original description is as follows:

"Body very large, swollen; rays six in number, in length somewhat less than twice the diameter of the disk. Upper surface covered with numerous short, blunt, equidistant spines, uniform in size and regularly distributed; these spines are somewhat conical in shape, but truncated at the tip and constricted at the base, with the sides longitudinally furrowed. The spines of the lower surface

are short and thick, but slightly compressed and notched at the extremity. Diameter, two feet. Taken in Tomales Bay, by Mr. Samuels."

Large photographs of the type, which is in the U. S. National Museum, have been furnished by Dr. R. Rathbun, for reproduction in our plates. Dr. Stimpson's description was very incomplete, for he scarcely described the ventral side at all.

The disk is rather large and the six rays taper rapidly to rather acute tips. They are variously bent, and wrinkled, indicating a rather weakly reticulated dorsal skeleton. The radii are about 73 mm. and 304 mm.; ratio, about 1 : 4.75.

The adambulacral spines are rather small, slender, compressed, crowded, and stand in a single row, one to a plate; they are much smaller and shorter than the crowded ventral spines. The latter form about eight close rows proximally, but these decrease to four or five at the distal third of the rays. They differ much in form. Those nearer the adambulacrals are partly fusiform and sometimes subacute, but more often flattened and subacute at the tip; those of the middle rows are stouter, either blunt, clavate, or flattened; those of the outer rows are still shorter and stouter, with blunt tips, but those near the base of the rays are apt to be fusiform and subacute.

The lateral or superomarginal row of spines is not very distinct; its spines are subacute and much smaller than the actinals. They form in some places two irregularly alternating rows, and differ but little, in size or form, from the dorsal spines, though they may be rather longer and more acute.

The dorsal spines are small, either obtuse or acute, roughly striated, very numerous, nearly uniformly scattered over the whole surface, mostly standing singly, and do not form reticulations nor any distinct median row. On the sides of the rays, in some places, they form small transverse groups or combs on the connective ossicles. About twenty to twenty-four can be counted in an irregular series across the rays at the base, but they form no evident transverse rows.

The spines become rather larger, longer, and more crowded near the ends of the rays, where they are surrounded by close wreaths of minor pedicellariæ. On the basal part of the rays and on the disk the minor pedicellariæ form small clusters around the bases of the spines, and many other dermal ones are scattered between the spines.

A few rather small, stout, subconical, dermal major pedicellariæ are scattered on the dorsal and lateral surfaces, and especially on the

interbrachial areas and intermarginal channels. The actinal spines bear small clusters of minor pedicellariæ on their outer sides.

This species appears to be very distinct from all others. Perrier placed it as a synonym of his *A. katherinæ*=*P. grayi* Ver., to which it bears some little resemblance in form. He was probably misled by Stimpson's very poor description.

Nothing is known concerning its range. Stimpson's original record is the only authentic locality known to me. Some of the localities recorded are due to errors.

PISASTER PAPULOSUS Verrill.

Plate XLII, figure 1; plate XLIII, figure 1; plate LX, figure 1; plate LXXVI, figures 2-2*d* (details); plate LXXX, figure 4.

Pisaster papulosus VERRILL, Amer. Journ. Sci., vol. XXVIII, p. 63, 1909.

The type of this species is a large dry five-rayed specimen, in excellent condition, taken in Puget Sound and sent to me by Professor T. Kincaid. A specimen received from the Provincial Museum of British Columbia, through Dr. C. F. Newcombe, but not in so good preservation, is much larger (diameter, 28 inches or 660 mm.). Thus, when full-grown it is one of the largest starfishes yet discovered.

The disk is large and remarkably high and plump, with a raised central pentagon, bearing ten groups of spines on the angles and sides, besides a central group; from the radial angles carinal radial rows of spines run to the tips of the arms, which are long, rather stout at the base, but regularly tapered to acute tips.

The radii of the type are 42 mm. and 215 mm. to 225 mm.; ratio, about 1 : 5.25; breadth of rays at base, 45 mm.; elevation of disk, 46 mm.; length of dorsal spines, 4 mm.; diameter, 1 mm.; length of larger ventral spines, 3 mm. to 4 mm.; diameter, 2 mm. to 2.5 mm.

The dorsal surface is covered with an integument that conceals the ossicles. The papular areas are large and numerous; a conspicuous row runs along each side of the median radial row of spines, and there are several less regular rows on each side. The papulæ are very numerous and small, darker than the surrounding integument, which is light yellowish orange in the dried specimen; the papular areas brown.

The dorsal spines are large, few, and mostly isolated, but they form a distinct, simple, radial or carinal row, one to a plate, proximally, but on the distal third of the ray these spines become more distant and the row less distinct.

On either dorso-lateral side there are similar, but rather sparsely scattered, spines, which mostly show no definite arrangement; but in some cases, distally, they have a tendency to form about three imperfect rows on each side. These spines are all rather large, up to 3 mm. to 4 mm. high, and about 1 mm. thick, tapered or conical, subacute or acuminate, and often pinched up near the tips and strongly sulcated. They bear large and dense wreaths of minor pedicellariæ placed around their bases as dried, and there are numerous large, dense clusters of similar pedicellariæ thickly scattered over the surface between the spines, and around the papular areas, as if taking the places of the spines that are present in other species. Many of these clusters are as large as those around the spines, or up to 3 mm. to 4 mm. in breadth. They are abundant on both the disk and rays, but become more numerous on the distal half of the rays, where they are often so crowded that in life they must form a nearly continuous coating. Large, stout, erect, dentate, dermal, major pedicellariæ are numerous, scattered over the whole dorsal and lateral surfaces of the rays. They are rather quadrangular in an end view; in a side view scarcely compressed, blunt wedge-shaped or stone-hammer-shaped. The tip of the jaws are serrate or unguiculate and subtruncate. The larger ones are about 1.5 mm. high and nearly 1 mm. broad.

The pentagon of the disk is formed by five radial clusters of stout conical spines, like the dorsal radials, standing about three together, and five similar interradial groups, standing a little nearer the center. The large, brown madreporic plate takes the place of most of those in one interradial space. A cluster of five spines occupies the center.

The large dorsal interradial areas of the disk are mostly without spines, but have an abundance of pedicellariæ and papulæ.

The upper marginal rows of spines are like the median, but they become more regular and the spines closer together distally. The channel below them is wide proximally, and bears many of the large, serrate pedicellariæ and numerous minor ones. The row of inferomarginal spines is strong, double, and regular, each plate usually bearing two spines, especially distally, to the tips of the rays. The distal spines are subacute and sulcate, much like the dorsals, but those on the proximal half are mostly stouter (2 mm. or more), with obtusely rounded and sulcated tips.

Close to these, but with an intervening papulose channel, is a regular, mostly single row, of peractinal spines, continuous to the tips of the rays. The spines are like the inferomarginals. A

shorter row of similar synactinal spines, extending to the distal third, intervenes between the peractinals and the adambulacrals, but is separated from the latter by a definite channel, having papulæ proximally. Close to the base of the rays some of the inferomarginal and actinal plates often bear two or three small extra spines, and all bear dense clusters of minor pedicellariæ on the outer side. The adambulacral spines form a single very regular row; they are slender, tapered, and subacute; about five correspond to a single actinal spine. The adoral ones become somewhat longer. Many of them bear thick clusters of forficulate pedicellariæ of various sizes in a single cluster. Between their bases and on the inner edges of the ambulacral grooves, and on the oral spines, and interradial areas are many large major pedicellariæ, part of which are unguiculate, like those of the back, but others are longer, compressed, lanceolate, with the tips subacute, or terminating in one or two hook-like teeth. The pedicels of these, and also of those attached to the spines, are often surrounded by large clusters of small forficulate pedicellariæ of nearly the same form, but of various sizes, many being as minute as the ordinary minor pedicellariæ. Friday Harbor, Puget Sound (Professor Kincaid).

The paucity of spines on the back of the specimen above described might be thought to be due in part to some injury and lack of subsequent restoration of the spines. But on the distal part of the rays, at least, the spines seem to be certainly normally arranged. There are no naked ossicles or tubercles where spines are likely to have been attached.

I have examined four additional specimens (No. 1904, Mus. Comp. Zoöl.) from the same district and also sent by Professor Kincaid. They are all larger. One of them agrees closely with the type specimen described above. Its radii are 110 mm. and 330 mm. Others, equally large, have the disk and rays flattened in drying and appear to have more numerous and larger spines and fewer pedicellariæ. One has the radii 85 mm. and 330 mm.

This species is rather closely related to *P. brevispinus* (Stimpson). But the characters of the dorsal spines and pedicellariæ and of the actinal spines, and the larger spines and papular areas, seem to require their separation. Of course a much larger series of specimens than I have studied might show intermediate forms, as in other cases. The difference in the number of rows of actinal spines is greater than we should expect in specimens of similar size. The dorsal spines are much less numerous in our species and the rays much longer

and more tapering. The characters of the adoral carina and oral spines are also peculiar.

VARIATIONS.

A very large dry specimen of this species has been sent to me by Dr. C. F. Newcombe from the Provincial Museum of British Columbia. It was dredged in ten fathoms, off Victoria, 1894.

Its radii are 64 mm. and 330 mm.; ratio, 1 : 5.14.

The disk is distorted in drying and is probably larger than the normal size. The rays are thick at base, but taper to long and relatively slender tips. The dorsal surface is covered with a thick integument, dark reddish brown in the dry specimen, and has but few distant spines. But numerous large, stout, thick, unguiculate pedicellariæ are scattered over the surface, which is also covered with small minor pedicellariæ, thickly scattered over nearly the whole surface and also forming wreaths around the bases of the spines. Probably a large part of these may have been rubbed off by repeated dustings, for the specimen has evidently been exposed to dust and mold; and owing to its great size, it probably was not very well preserved originally. Hence it is probable that the dermal minor pedicellariæ originally existed in still larger clusters, as they do in depressed spots, where the coating of dust and mold has not been removed, especially distally. But as numerous large major pedicellariæ are still scattered over the surface, it is evident that no severe cleansing has taken place, sufficient to remove all those on the spines.

The dorsal skeleton is coarsely and irregularly reticulated, but the ossicles are concealed by the thick integument.

The spines are mostly conical and acute or subacute, about 1.5 mm. to 2.5 mm. long, with but few smaller ones. They form distinct but incomplete simple radial rows, in which they usually stand 2 mm. to 5 mm. apart, where continuous. A very few similar spines are irregularly scattered over the disk and rays. The madreporic plate is large, with fine gyri, its diameter is 13 mm.

The superodorsal plates are well down on the sides of the rays. They are relatively small and not very distinct, and bear a simple row of spines, rather larger than the dorsals, many of them blunt with grooved tips. They are close to the inferomarginals, except in the interradial areas, where they diverge a little, leaving a spineless area.

The ventral spines proximally consist of four or five rows close together and nearly equal. They are short (3 mm. to 4 mm. long),

stout, mostly blunt or truncate and striated at the tip; but close to the bases of the rays they become longer. Some are acuminate and subacute. On the distal third of the rays there are only three rows, besides the superomarginals, there being but one row of actinals distally.

The inferomarginal ossicles are rather large, thick and convex, roundish on the outer end, and usually bear two or three divergent spines, which are mounted on low mammillæ with a central pit. The peractinals are similar in form externally, and mostly bear but one spine, but sometimes two proximally. The principal row of subactinal plates, proximally, are large and transversely broad in their internal part, but show only a rounded exterior surface, smaller than the other plates and bearing a single spine. Between these, proximally, there are a few smaller wedge-shaped or irregular subactinal ossicles, interpolated irregularly and mostly without spines. The inferomarginal and actinal plates are closely crowded together.

There is a rather wide naked channel between the synactinal and adambulacral plates, due to the great transverse length of the latter externally to the single spine that stands on the inner edge.

The adambulacral spines are slender and tapered, mostly 5 mm. to 7 mm. long, becoming still longer near the mouth.

Large major pedicellariæ, like those of the type, occur among the actinal adambulacral spines and along the inner edge of the grooves. These are long-ovate or lanceolate, with acute or subacute jaws, often toothed. With these there were others of various smaller sizes, of nearly the same forms.

THE YOUNG.

A small specimen, from Sitka, has the radii 10 mm. and 45 mm.; ratio, 1 : 4.5.

The dorsal spines are few and sparse, except along the median radial rows, where they form pretty close and nearly regular simple rows. A very imperfect, irregular row also occurs on each side, about midway between the median and superomarginal rows. Ten small groups of about two or three spines each form a central pentagon, with three central spines. Elsewhere dorsal spines are mostly lacking. All these spines are short, cylindrical or slightly clavate, with obtuse, sulcated tips. The dorsal ossicles are rather large and broad; even those that are without spines are often lozenge-shaped; those that bear spines are convex centrally, with a mammilla and pit. The superomarginal spines form a regular simple

row; they are smaller than the dorsals, but of the same form. The inferomarginal spines stand mostly two on a plate and with the peractinals form three regular nearly equal rows. They are larger than the superomarginals and either cylindrical or slightly tapered, obtuse, finely sulcate. The peractinals are rather smaller than the rest and less obtuse.

Adambulacrals form a single row; they are about as long as the actinals, but much more slender and evenly tapered. Three or four of the inner adoral plates, forming the compressed carinæ, are without spines.

A few large, ovate, unguiculate pedicellariæ occur on the lateral channels and adambulcral plates. Some smaller acute-lanceolate ones occur on the inner edges of the grooves. Minor pedicellariæ are rather thickly scattered everywhere over the dorsal and lateral integument.

Another young specimen of larger size, with the radii 16 mm. and 82 mm., was sent by Dr. C. F. Newcombe. It was taken at Kuper Island, B. C., February, 1894. This agrees closely with the smaller one, described above, in the number and character of its dorsal spines, but the ventral spines are relatively stouter and form four rows proximally.

The dorsal minor pedicellariæ are much more numerous, both on the integument and around the spines, especially distally, where they form large dermal clusters. The papular areas are also very large, with numerous papulæ. Thus it has in most respects the characters of the adult.

Large major pedicellariæ are rather numerous on the interradial areas and sides of the rays; and many large, very acute, lanceolate ones occur on the inner edges of the grooves, sometimes in regular rows, one to a plate, for some distance. Most of these are surrounded at base by clusters of smaller major pedicellariæ of about the same shape, but of various sizes.

This specimen is remarkable for having two spines on some of the adambulacral plates, here and there, the second spine being smaller and attached back of the regular one. This condition has not been noticed in the other specimens.

The adoral carinæ are rather long and strongly compressed, descending abruptly to the mouth in all our specimens, and destitute of spines on three or four adoral plates. Apical peroral spines long, tapered, about equal to adorals, side-spines apparently lacking, or replaced by a cluster of pedicellariæ; epioral spines lacking on our specimens.

This species ranges from Puget Sound to Sitka. Puget Sound (Professor Kincaid); Kuper Island and Victoria (C. F. Newcombe); Sitka (Harriman Expedition, W. R. Coe).

PISASTER GRAYI Verrill, nom. nov.

Asterias katherinæ PERRIER, Stellér. du Mus., Archiv Zool. Expér., IV, p. 331, 1875 (*non* Gray, 1840).

Asterias dubia VERRILL, Amer. Naturalist, XLIII, p. 545, 1909 (*non* Clark).

Perrier evidently erred in his determination of Gray's type of *A. katherinæ,* for Gray stated that his species had two spines on each adambulacral plate, as I have elsewhere explained.[1]

According to Perrier it has the following characters:

Ordinarily six rays, sometimes five, upper side of the body little convex, rays broad at the base, pointed at the tip. Radii as 1:7. Between tips of rays about 4 decm. Adambulacral spines in a single range,[2] with some small clusters of major pedicellariæ upon the outer side. Immediately beyond these comes a band of stouter ventral spines, formed by transverse ranges of two or even three spines. A narrow channel separates this band from another simple range of spines, representing the lateral spines. Then comes a pretty wide naked band, and a very irregular range of shorter spines, which indicates the commencement of the dorsal region. The latter is covered with numerous short spines, with the head rounded and strongly striated; sometimes isolated, sometimes in groups of two or three, but disposed without order. A circle of minor pedicellariæ, small in number, surrounds the base of these spines. Some small major pedicellariæ are scattered between them, but these are particularly numerous on the sides, between the back and and the line of lateral spines, in the channel that separates this line from the band of ventral spines, and between the latter and the adambulacral spines. These major pedicellariæ have the form of a short isosceles triangle with a pretty large base. The madreporic plate is marginal. Color, when dry, red.

Gray gave the locality of his specimens as "Mouth of the Columbia." This locality is uncertain, however; for his specimens, as labelled, were a mixed lot. (See p. 113, below.)

Perrier regarded *A. gigantea* Stimpson as a doubtful synonym of this species, to which it is possibly related. But *gigantea* has a much

[1] Gray's true type is doubtful. (See page 113.) It could not have been this species.

[2] This does not agree with Gray's statement. (See below, p. 112.)

larger disk and shorter rays. The latter also has more numerous rows of actinal spines, while the dorsal spines are conical, numerous, and evenly scattered. Nor does Perrier mention the large serrate, lateral pedicellariæ found on the latter.[1] Still it may prove to be the young of *P. giganteus,* for we know very little about the variations of the latter.

I have seen no specimens agreeing well with the description given by Perrier.

PISASTER ? PAUCISPINUS (Stimpson) Verrill.

Plate XXXVI, figures 1, 2 (types).

Asterias paucispina STIMPSON, Proc. Boston Soc. Nat. History, VIII, p. 266, 1862. Perrier, op. cit., 1875, p. 324 (no description). Bell, op. cit., p. 495 (no description).

This species is easily recognized by its rather angular rays, few actinal and dorsal spines, and uniserial adambulacral spines. Stimpson's description is as follows:

"Rays five, high, trigonal above, rounded below; disc rather large. Proportion of the diameters, 1 : 4.75. Skin-skeleton less firm than in the four preceding species, the net-work being more open. Ambulacral pores in four regular rows. Ambulacral spines in one very regular row, equal, not crowded, slightly compressed, and slightly tapering, with blunt extremity. A considerable number of sharp, appressed major pedicellariæ, of variable size, may be seen on the inter-ambulacral plates at the inner bases of the ambulacral spines, together with a few small clusters of the minor kind. Ventral spines of moderate size, cylindrical, tapering to a blunt tip not striated, and arranged in three rows, or in about thirty transverse rows of three each, the two outer ones placed together on each of the ossicles of the single ventral [inferomarginal] series, and the inner one on the transverse connective piece [actinal plate] which passes to the marginal interambulacral plates. Each of these transverse rows corresponds to five ambulacral spines. A small cluster of minor pedicellariæ at the outer base of each of the ventral spines, most prominent in those of the outer row. Lateral channel distinct, with a row of stout, narrow, wedge-shaped major pedicellariæ, extending from the base of the ray to the middle of its length. Dorsal spines equalling the ventrals in size, less than one-twelfth inch in height, and subcapitate, with conical, truncate, and striated

[1] If these were absent the species may not be closely related to the *Pisaster* group, especially as there are few actinal rows of spines.

heads. They are few in number, and are arranged in five regular rows; those of the marginal row, twenty-five in number, being a little smaller and more elongated than the others; median row consisting, like the marginal row, of twenty-five spines, one to each ossicle; intermediate row with only ten spines, and becoming "zigzag" toward the extremity of the ray. On the disc there is a regular pentagon of about ten spines, one (rarely two) to each angle, and one (rarely two) at the middle of each of the concave sides. No spines within the pentagon except one central one, which is always present; madreporic plate within the pentagon, at the periphery. Minor pedicellariæ are scattered, in clouds, over the dorsal surface, but there are more of the major kind on the back. Papulæ in groups. Diameter, four and a half inches.

"Habitat, Puget Sound—North West Boundary Commission. Dr. C. B. Kennerly. This fine species is common in the circumlittoral zone." (Simiahmoo.)

The figures are from photographs of Stimpson's original types in the U. S. National Museum. They were furnished by Dr. Richard Rathbun. These specimens are probably immature.

Label: "Nor Boundary S A. Campbell 1286 Asteri paucispin Puget Sound eahmoo) C Kennerly Fig. 2 in Th

VARIATIONS.

A purchased specimen in the Museum of Yale University, labelled simply as from the "West Coast," agrees closely with Stimpson's type, except in characters due to its smaller size. Its radii are 10 mm. and 39 mm.; ratio, about 1:4. The rays are high and somewhat carinate. The dorsal ossicles are not numerous, rather stout and broad, but have rather broad rounded papular areas; the ossicles of the median row are small but prominent, each bearing, near the base of the arm, two short obtuse or subcapitate spines, but distally only one. Between the median and the superolateral row there is a single row of fewer, larger, obtuse spines, with striated ends. The superomarginals are a little longer and somewhat conical, one to a plate. The pentagon of spines on the disk has usually two or three spines at each angle, one or two on each side, and two on one ossicle in the middle; all these are capitate and striate. Madreporic plate raised, wart-like, with fine radiating gyri. The under side is nearly as described by Stimpson.

The adambulacral spines are uniserial, very slender, terete, tapered, subacute. The synactinal plates are small, rounded, and prominent, extending to about the distal fourth of the ray, each bearing a spine like the inferomarginals, but rather smaller. The latter, which

The Type has the peculiar Pisaster str. D fed. on ends, and heavy ovate str. fed. in interma

mostly stand two to a plate, are tapered, subacute or obtuse, but not striated at tip.

Large major pedicellariæ occur in the naked channels between the upper and lower marginal plates, especially proximally; these are compressed in a dorsal view, but long-ovate or lanceolate in a side view, not serrate. These are more than half as thick as the adjacent spines; others of much smaller size, but similar in form, occur on the interradial areas below, and along the margin of the grooves. The minor pedicellariæ are very small and occur both on the spines and on the papular areas.

This species may belong with *Marthasterias* rather than with *Pisaster*. More specimens are needed. Perhaps larger specimens would have more rows of interactinal plates.

Genus **Marthasterias** Jullien.

Asterias (*pars*) GRAY, Sladen, Bell, etc.
Marthasterias JULLIEN, Bull. Zool. Soc. France, 1878, p. 141. Type, *M. foliacea* = *M. glacialis* (Müll.).
Stolasterias, subgenus (*pars*), SLADEN, op. cit., 1889, pp. 563, 583.
Stolasterias (restr.) PERRIER, Expéd. Trav. et Talism., pp. 108, 109, 1894.

Monacanthid, five- or six-rayed Asteriinæ, with few definite radial rows (usually three) of stout dorsal ossicles and large spines. One row of small or rudimentary actinal plates, usually without spines. Upper and lower marginal plates large, with long spines. See also p. 47.

MARTHASTERIAS (?) SERTULIFERA (Xantus) Verrill.

Asterias sertulifera XANTUS, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 568. Ives, List Cab. Stearns, p. 2, 1890. De Loriol, Recueil Zool., Suisse, II, 1887.

Rays five, subangular. Radii, about 1 : 5; diameter, about 112 mm. Adambulacral spines in one row, very slender, flattened. Ventral spines in two or three rows, stouter, blunt, and flattened. Upper marginals regular, one spine to each alternate plate. Dorsal spines similar, stout, cylindrical or tapered, in three pretty regular rows, all bearing dense wreaths of minor pedicellariæ near their tips. Major pedicellariæ few. (Xantus.)

Cape St. Lucas (Xantus); San Diego (Ives, 1890); California (De Loriol).

I have had no opportunity to study well preserved examples of this species, and therefore refer it to *Marthasterias* with doubt.

Genus **Asterias** Linné (restricted). See page 43.

Asterias (*pars*) Linné, Syst. Nat., ed. x, 1758; ed. xii, p. 1098, 1766. Gray (restr., *pars*), 1840; Synopsis, p. 1, 1866. Perrier (*pars*), Révis. Stell., op. cit., iv, p. 302, 1875. Bell, System. Arrangement, Proc. Zoöl. Soc. London, 1881, p. 492.

Stellonia (*pars*) Nardo, Oken's Isis, p. 716, 1834. Agassiz, Prod., p. 191, 1835.[1]

Uraster (*pars*) Forbes, Mem. Wernerian Soc., viii, p. 114, 1839.

Asteracanthion (*pars*) Müller and Troschel, Monatsb. Akad. wiss., Berlin, p. 102, 1840; Syst. Ast., p. 14, 1842. A. Agassiz, North Amer. Starfishes, p. 94, 1877 (structure).

Asterias Norman, Ann. and Mag. Nat. Hist., ser. 3, xv, p. 126, 1865.

Asterias (*pars*) Sladen, Voy. Chall., xxx, p. 560, 1889. Perrier, Exp. Trav. et Talism., p. 108, 1894.

Diplasterias (*pars*) Perrier, Exp. Trav. et Talism., p. 108, 1894.

As here restricted, this genus is characterized by having the larger dorsal ossicles well developed, with three or four lobes, united in a reticulated or irregular manner, and with oblong transverse ossicles, uniting the longitudinal series, and thus leaving relatively large, irregular papular areas, from which arise clusters of few or numerous small papulæ. The median radial dorsal ossicles usually form a distinct row, with spines more prominent than the others. The interactinal plates usually consist of only one or two (sometimes three) rows, including the synactinal or connective plates, all of which are usually so united as to leave papular areas. (See p. 33 above.)

The adambulacral spines may stand either one or two to a plate, but very commonly they are alternately or irregularly one and two. The actinal and lower marginal spines usually form three to five rows, which are longer and larger than the dorsal spines, and in large specimens often stand two or three on one plate. The superomarginal or lateral spines generally form a distinct row, leaving a lateral naked lane or "channel" between it and the lower marginals; a small series of ossicles may sometimes be interpolated in this area, at the bases of the arms. The dorsal spines may be of almost any shape, but are generally shorter than the marginals and actinals and often different in form. The spines are generally surrounded by groups or wreaths of forcipate or minor pedicellariæ, but similar pedicellariæ may be scattered between the dorsal spines, or among the papulæ, or they may form dermal clusters.

[1] The genus *Stellonia*, as understood by L. Agassiz (Prod., p. 191, 1835), included not only the present genus *Asterias* (sens. ext.), but also *Echinaster*, *Solaster*, *Heliaster*, etc. The first species cited was *S. rubens* (L.).

The forficulate or major pedicellariæ are usually lanceolate or ovate, and more or less compressed; they may be scattered between the dorsal spines, around the papular areas, but are more constantly present on the ventral interbrachial areas, and on the naked channel or lane between the upper and lower marginal spines; they frequently occur on the adambulacral and interactinal spines, where they are usually of smaller size, and also within the edge of the ambulacral groove, attached to the adambulacral plates, when they usually have longer pedicels. They generally have characteristic forms in each species. In some large specimens they may be almost lacking, though abundant in others of the same species. In very young specimens they are usually few or lacking.

The genital ducts, in all those species dissected, are connected with a pair of small genital pores on the dorsal side, in the interbrachial areas.

The ambulacral feet and pores are generally in four rows, but may be so crowded as to form six apparent rows, near the base of the rays. These forms all have great powers of restoration and repair after injury, being able to replace large portions or all of the disk as well as part or all of the rays, but spontaneous fission has not been observed in any of the typical species, all of which, so far as studied, develop from a free-swimming brachiolarian larva, in contrast with the species of the genus *Leptasterias,* which have no free-swimming stage, for their eggs and larvæ are attached in clusters to the oral region, till capable of creeping. They have ventral genital pores.

ASTERIAS VICTORIANA Verrill.

Plate LIII, figure 1 (dorsal); plate LIV, figures 1, 2 (actinal and lateral); plate LXIX, figure 4; plate LXXXII, figures 1-1*c* (details).

Asterias victoriana VERRILL, Amer. Journ. Sci., XXVIII, p. 68, 1909.

Rays five, stout, rather rapidly tapered. Radii, 20 mm. and 95 mm.; ratio, 1 : 4.75.

Dorsal skeleton conspicuously reticulated, leaving large papular areas, which are mostly rounded or somewhat elliptical, the transverse diameter the greater. The intervening ossicles are strong and prominent above the surface, as narrow convex ridges; those at the intersections and in the radial rows larger and deeply four- to six-lobed, convex in the middle, with a central mammilla and pit where the spine is attached.

The ossicles of the two marginal rows and next two actinals are thick, nearly equal in size and form, and proximally stand in four

or five regular rows; the upper marginals are a little more removed, but the others are closely united in a tesselated manner, leaving only small papular pores between them. The exposed part is convex, with facets and pits for the spines. They are slightly four-lobed, but are so imbricated that they appear squarish with rounded corners, or ovate-triangular.

The dorsal spines consist of two very unequal kinds. The larger ones are few in number and are widely scattered, except in the median radial line, where they form a pretty regular row; the others stand somewhat in quincunx, but may belong to about three imperfect rows on each side. These spines stand on the larger plates at the intersections of the reticulations. They are rather large, short, and thick, not much higher than broad, with enlarged, truncate or capitate tips, striated on the sides and rough on the top. They are about 1.5 mm. broad. Between these there are many very small inconspicuous spines, arranged mostly in single rows along the narrow ossicles that form the sides of the reticulations. Some of them are acute, but most are slightly clavate with rough or spinulose tips. Both kinds are scattered irregularly on the central area of the disk.

Small minor pedicellariæ are thickly scattered over the whole surface between the spines and on the papular areas, and also form wreaths around the larger spines.

The superomarginal spines form simple regular rows, and are much like the large dorsals in length and form, but are smaller. The intermarginal channel is well defined and of moderate width. The inferomarginal spines form a regular row, mostly simple, but frequently stand two on a plate distally. They are followed, proximally, by two pretty regular close parallel rows of actinal spines, of about the same size and shape. These three rows of ventral spines are longer than the superomarginals and less clavate, but about as stout. They are blunt and sulcate at the tips. The first subactinal row extends only to about the end of the proximal third of the ray; on the proximal fourth there is also a simple, short row of synactinal spines.

The synactinal ossicles are small, with an oblong or elliptical surface, and mostly bear a single spine; they extend only to about the proximal third of the rays.

The adambulacral spines stand two on a plate, or else in certain parts one and two alternately, thus forming two or three crowded rows. They are unequal, not very slender, the inner ones slightly tapered, the outer ones stouter, blunt, as long as the ventral spines,

but more slender. They increase somewhat in length and thickness toward the mouth.

The two apical peroral spines are rather stouter and shorter than the adorals; their side spines are about half as long and more slender. The epioral spines are like the adorals.

The adoral carina is rather thick and stout, composed of three pairs of contingent plates beyond the epiorals, the third pair bearing two spines.

Major pedicellariæ of moderate size occur among the ventral spines and on the lateral and dorsal surfaces, but are not numerous. They are compressed, lanceolate or acute-ovate, with sharp tips.

The type of this species was from near Victoria, B. C. (Prov. Mus. B. C., coll. Dr. C. F. Newcombe).

ASTERIAS POLYTHELA Verrill.

Plate LV, figures 1, 2 (dorsal); plate LXX, figure 8; plate LXXII, figure 2; plate LXXXIV, figures 3, 4 (details); plate LXXIX, figures 1-2*a* (details).

Asterias polythela VERRILL, Amer. Journ. Science, XXVIII, p. 68, 1909.

Rays six, stout, of moderate length, rounded and with a firm skeleton. Radii, 20 mm. and 80 mm.; ratio, 1 : 4.

Dorsal surface appears rough and rugged. It bears an irregular number of large, stout, round spines, arranged without order, except that in a few places two or three may stand in a median series; elsewhere they may be grouped, two to five, near together, or stand singly. These spines stand on raised central bosses of the plates; they are constricted somewhat at base and then abruptly enlarged below the middle; the terminal part is regularly tapered or somewhat acorn-shaped or nipple-shaped, longitudinally finely grooved, ending in a blunt apex. They are 2 mm. to 4 mm. high and 1.5 mm. to 2 mm. in diameter. Scattered over the whole surface are many small, unequal, short, acorn-shaped and capitate spines, mostly from 2 mm. to 4 mm. in diameter. The large and small spines are all surrounded by close wreaths of small minor pedicellariæ; clusters of these are also attached to the skin, so that the surface appears to be almost covered with them.

The marginal and actinal rows of spines are pretty regular and smaller than the dorsals. The upper marginals stand mostly one to a plate proximally and two to a plate distally. They are shaped somewhat like the large dorsals and nearly as long, but only about half as thick. The lower marginals are about as long, but stouter; they

stand either one or two to a plate. A short row of smaller spines is interpolated between the upper and lower marginals proximally. The peractinal spines are like the lower marginals proximally and form a regular row, one to a plate. The adambulacral spines are small, round, blunt, mostly two to a plate, sometimes one in certain parts, divergent and almost concealed by large clusters of small, ovate, major pedicellariæ on the inner ones, and clusters of major pedicellariæ on the outer ones; many large clusters of major pedicellariæ are attached to the inner edge of the plates within the furrow. A few much larger, blunt-ovate, major pedicellariæ with finely denticulate jaws, occur on the interradial spaces and between the proximal marginal spines.

The type was taken off the Arctic coast of Alaska by the U. S. R. S. "Corwin" in 1885, No. 16889 (U. S. Nat. Mus., No. 15820).

ASTERIAS NANIMENSIS Verrill, sp. nov.

Plate LXI, figures 1-1*b* (dorsal and actinal sides).

Rays five, long, narrow, tapered, nearly half-round, the height about equal to the breadth as dried. Radii, 180 mm. and 18 mm.; ratios, 1 : 10. Whole upper surface of rays and disk pretty regularly reticulated by the lobed plates and ossicles, each plate bearing a single central terete spine, 1.5 mm. to 2 mm. high, with a blunt fluted tip. These spines, on the rays, are arranged nearly in quincunx, but the median dorsal row is distinct, with the spines pretty regular and close together. The upper marginal row is distinct but scarcely different from the dorsals. Between the upper marginals and the median row there might be reckoned four or five zigzag and irregular rows, but the arrangement is rather reticulate. The dorsal spine-bearing plates are small, with a central boss and usually four or five lobes, giving a stellate form, the lobes united to those of adjacent plates by one or two small ossicles, thus leaving rather large, quadrangular, rhombic, or pentagonal papular areas between them. Large dense clusters of minor pedicellariæ surround the bases of all the dorsal and marginal spines, and the outer sides of the peractinal spines. The upper marginal plates are much like those above, but rather stouter and in a more regular row; their inferior lobe is larger and stouter than the others, is shoe-shaped, and joins the upper lobe of the lower marginal plates, usually without an intervening ossicle, leaving a well defined narrow marginal channel with large quadrangular papular areas between them. The

lower marginal plates are similar and equal in number, but more regular. Each bears a single spine much like the dorsals in size and form. Below this row there is a wide naked channel with large papular areas, like those above it. Between this row and the adambulacral plates there is only one row of plates. These are reckoned as peractinal plates. They correspond in number and size with the marginals and are placed close to the adambulacrals, which they join generally with no connecting ossicles between; when rarely such ossicles occur, they are few and very small or rudimentary. In the narrow channel between the peractinal and adambulacral plates there is a row of small papular areas, each with one or few rounded papulæ. Each peractinal plate bears two strong equal spines, decidedly larger and longer than the marginals, the proximal ones 2 mm. to 3 mm. long. Their tips are usually flattened, and often enlarged and fluted or grooved.

The adambulacral spines are numerous and regular, two to a plate, forming two close rows; they are tapered, blunt or subacute, about four pairs corresponding to one peractinal plate. Major pedicellariæ are few on the type. Those found were on the adambulacral spines and inner margins of their plates. They are rather large, lanceolate, acute, about as thick as the adjacent spines. None were found on the back.

The disk is reticulated much like the rays, with large angular interspaces. The madreporite is large (5 mm.), prominent, with radiating and dichotomous gyri. It is surrounded, in the type, by seven spines, like the other adjacent spines.

The central disk-spine rises from a five-lobed plate. It is surrounded by five spines, and beyond this with a circle of ten spines.

The type is from Departure Bay, Nanaimo, British Columbia, twenty-five fathoms, mud (Chas. H. Young, Canadian Geological Survey, 1909).

This species seems to be closely related to the genus *Orthasterias,* in several respects, and especially to *O. kœhleri,* by reason of the rather indefinite or sublongitudinal arrangement of its dorsal spines, in about seven obscure rows. It differs from the latter in the shorter, stouter, fluted and crowded dorsal spines; the prominent median row; the double peractinal row of elongated spines; etc.

ASTERIAS ACERVATA Stimpson.

Plate XXVII, figures 1, 2 (var. *acervata*, type); plate CVI, figure 3 (var.).

Asterias rubens (*pars*) and *A. minuta* (*pars*) FABRICIUS, Fauna Groenl., pp. 367, 370, 1780 (*non* LINNÉ).

Asterias violacea SABINE, Suppl. Parry's Voyage, p. CCXXIII, 1824 (*non* Müller).

Asteracanthion polaris MÜLLER and TROSCHEL, Syst. Aster., p. 16, 1842 (young). Steenstrup, 1855, p. 240. Lütken, Vidensk. Meddel, 1857, pp. 28, 29, 1857. Perrier, Ann. Sci. Nat., Paris, pp. 33-36, pl. 1, fig. 6, 1869. Duncan and Sladen, 1878, pp. 265, 266, 1878; ditto, Echinod. Arctic Sea, pp. 23-27, pl. II, figs. 4-8, 1881.

Asterias polaris STIMPSON, Proc. Boston Soc., VIII, p. 271, 1862. Verrill, Proc. Boston Soc. Nat. Hist., X, p. 356, 1866; 1867, p. 268; Amer. Journ. Sci., XI, p. 420, 1876; Amer. Journ. Science, XLIX, p. 208, 1895; in Packard, Fauna of Labrador, p. 268, 1867. Perrier, Arch. Zool. Expér., pp. 332, 357, 1875 (Greenland examp. described). Bush, Proc. U. S. Nat. Mus., VI, p. 246, 1883. Sladen, Voy. Challenger, XXX, p. 826, 1889. Ludwig, Fauna Arctica, I, p. 485, 1900 (distribution), *non* Sabine, 1824.

Asterias acervata STIMPSON, Proc. Boston Soc. Nat. Hist., VIII, p. 271, 1862. Bell, op. cit., 1881, p. 494. Murdoch, Report International Polar Exped., p. 158, 1885. Ludwig, Echinod. des Beringsmeeres Zool. Jahrb., p. 287, 1886; Fauna Arctica, I, p. 485, 1900. Sladen, Voy. Chall., XXX, p. 818, 1889. Bell, 1881, p. 494.

Asterias borealis PERRIER, Arch. Zool. Expér., IV, pp. 323, 357, 1875 (descr. Labrador example). Bell, op. cit., 1881, p. 497.

Asterias douglasi PERRIER, Révis., Arch. Zool. Expérim., IV, pp. 333, 357, 1875 (based in part on one of Gray's supposed cotypes of *A. katherinæ* = *A. polaris*, teste Perrier, in note, p. 357). Bell, Arrangement, p. 497, 1881.

Of the true Atlantic *polaris*[1] I have examined large numbers of examples, in various collections, and have also collected it myself on the southern coast of Labrador and at Anticosti Island (1861), where it is common at low tide among the rocks, often associated in that region with *A. vulgaris*, which it resembles in size and color.

Among hundreds of specimens, I have never seen one with five rays, though such are said to occur very rarely.

The size, form, and arrangement of the dorsal spines vary widely, as in all the allied species, but still the general appearance is pretty characteristic. The dorsal spines are always numerous, capitate (or when more slender, clavate), and always more or less clustered or acervate, unless in very young examples.

In large Labrador specimens, seven to nine inches in diameter (larger radii may be 100 mm. to 150 mm.), the dorsal spines

[1] This form should be called *Asterias acervata borealis*, since *A. polaris* is a preoccupied name.

become much more numerous and more conspicuously clustered than in those of the ordinary sizes.

The upper and lower marginal spines are conspicuously longer than the dorsals and are usually tapered. They commonly stand singly on each plate and form a simple row in each series on the basal part of the rays, but distally the upper row usually becomes double, with two spines on each plate. A short lateral row is often interpolated between the two marginal series.

The actinals are like the marginals and form one continuous and usually simple row, close to the lower marginals. The marginal and actinal plates are stout, wide, and closely joined.

The subactinal spines are rather smaller and do not usually extend beyond the basal third of the rays; they are close to the adambulacrals. The latter are biserial, but an occasional plate bears but one spine; they are slender, tapered, and terete, and carry conspicuous clusters of minor pedicellariæ.

The major pedicellariæ of the Labrador *borealis* are very variable in size, just as Stimpson describes those of *acervata*. Those scattered on the back are very small, short-ovate; those on the lateral channels are much larger, but not unusually large, and vary from short-ovate to triangular-ovate; most of them are short, with very obtuse tips, and are not distinctly serrate externally. Some specimens have only a few of these pedicellariæ, and of smaller size than usual.

The color in life varies from pale red or pink to purple and pale violet.

The name *A. polaris* is preoccupied by *Asterias polaris* Sabine, 1824.

The original type of Dr. Stimpson's *Asterias acervata* is still preserved in the U. S. National Museum. Photographs of it have been sent to me by Dr. R. Rathbun for reproduction. (See pl. XXVII, figs. 1, 2.)

Dr. Stimpson gave the following description:

"Rays six, more convex and more tapering than in *A. polaris*. Disc of moderate size. Proportion of the diameters, 1 : 4.5. Ambulacral spines in two rows (two to each plate), rather stout, cylindrical, and thickly covered with minor pedicellariæ near the tips. Ventral spines standing in two or three irregular rows. Lateral channel not well marked, and sometimes occupied by very small spines. Lateral spines standing singly in one row, and more pointed than the ventrals. Dorsal spines more numerous and crowded than

in *A. polaris,* and of greater diversity in size, the larger ones being collected in heaps which form three regular longitudinal rows on the rays. These large spines are capitate, with obtusely conical and striated heads; there are usually about six spines in each heap, the central one being much the largest and overtopping the others, which form a circle around it. The small spines between the heaps are quite uniform in size, and have globular tips. Disc surrounded by a ring of six heaps of spines, within which there is sometimes another ring of the same number, and always a heap in the middle. Madreporic plate surrounded with a circular canal and a ring of thirteen spines. All the spines, both ventrals and dorsals, are surrounded by minor pedicellariæ, as in *A. polaris.* The major pedicellariæ, which are most numerous on the sides of the rays, are scattered, and very irregular in size, varying from one two-hundredth to one-twentieth of an inch in length; the largest ones are stout, as long as broad, conical, or almost globular, having valves with broad, dentated extremities. Papulæ numerous, scattered, and often forming groups. Color, in life: above, clouded with very dark brown; madreporic plate cream-colored. Sides of rays, and inferior surface, of a yellowish cream-color. Diameter, five and a half inches.

"Habitat, Behring's Straits, on clean gravelly bottoms, in from five to fifteen fathoms. U. S. North Pacific Expedition. Wm. Stimpson."

Dr. Stimpson was the naturalist of the North Pacific Exploring Expedition, under Ringold and Rogers, and therefore probably made his notes on the colors from personal observation of living specimens.

I have received from the U. S. National Museum a specimen from Cape Smith, Alaska (No. 7630), which agrees very closely with Stimpson's type. The radii are 15 mm. and 55 mm. The dorsal spines are formed as described by Stimpson and are conspicuously acervate; but though the clusters are somewhat in three radial rows on the rays, the rows are decidedly irregular. Between the clusters the ossicles are obviously areolate or reticulate, and bear small capitate spines. The upper marginal spines are about equal in thickness to the larger dorsals and rather longer; they stand either one or two on a plate. The lower marginals are longer but not so stout, and form a regular row, one to a plate. There is a short intermarginal row of smaller spines proximally. The peractinals are similar to the lower marginals and form a regular, simple row close to the latter. Subactinal row short. The adambulacral spines are irregularly diplacanthid; they are moderately long, scarcely tapered, obtuse.

Cape Smith, Alaska (Murdoch, Point Barrow Expedition, 1884).

A young specimen of *acervata* (U. S. Nat. Mus., No. 6082), from Nazan Bay, Alaska, collected by Dr. W. H. Dall, in 1872, at low tide, differs considerably from the type. This is probably due largely to immaturity. The radii are 16 mm. and 48 mm. The principal dorsal spines are short, capitate, and form numerous small, but conspicuous raised clusters on the disk and median zone of the rays, but are lacking on the superolateral surfaces, where there are two pretty regular rows of very small capitate spines and some scattered. The median clusters are so crowded that they are often in contact proximally. The two marginal and the peractinal rows are regular, one to a plate, except that the upper marginals are double distally. The upper marginals are short, capitate, nearly as large as the larger dorsals; those of the lower marginal and peractinal rows are larger, not so stout, clavate or subclavate. The adambulacral spines are numerous, subdiplacanthid; distally they are clavate, but become longer, more slender, and subacute near the mouth. The pedicellariæ are similar to those of the preceding form, but less numerous; the large dermal ovate-lanceolate pedicellariæ are present. The apical plate at the tips of the rays is rather large and the small spines are thickly clustered around it.

Ludwig (op. cit., 1900) suggested that *acervata* is identical with *A. camtschatica* Brandt (op. cit., 1835). If this could be proved, the latter name would have priority over all the others. But Brandt's description, which was based on a colored drawing of a young or small six-rayed starfish (diameter of disk one inch, length of rays one to one and one-fourth inches), is far too imperfect to be of much value by itself for the identification of a species of this genus.

I have elsewhere given as good or better reasons for identifying his species rather with a different one (*A. multiclava*) found on the Siberian coast (see p. 114), but his description would apply as well, also, to forms of *L. epichlora.*

On the Atlantic coast this Arctic species extends southward to the Gulf of St. Lawrence, at Anticosti Island, etc., and to Newfoundland and the fishing banks off Nova Scotia, but not to New England. It is common on the Labrador and Greenland coasts as far north as north latitude 70°, at least. On the Pacific side it is found in the Arctic Ocean and on the coasts of Bering Sea and the Aleutian Islands, but so far as positively known to me it does not occur on the southwest coast of Alaska. It is also known from Siberia. A typical specimen of *acervata,* received from the U. S. National

Museum (No. 7630), was found on the beach at Cape Smith, Alaska, October, 1881, by Mr. Murdoch (Point Barrow Expedition). The young specimen described above was from Nazan, Alaska (W. H. Dall).

Ludwig (op. cit., 1886, p. 287) refers to *A. acervata* as follows:

"Of this species, which has become known through Stimpson, there are a number of examples, the largest of which measures 17.5 mm. The specimens come from Bering Strait, from a depth of from five to fifteen fathoms, and according to their exact localities are divided as follows: Two specimens from Lorenz Bay; one full-grown and one quite young specimen from Emma Harbor, Plover Bay; one specimen from St. Matthew's Island; one specimen from northwest of St. Matthew's Island, at a depth of twenty-five fathoms; one specimen from St. Paul's Island; three specimens without definite locality, from a depth of from twenty-three to twenty-five fathoms. All the foregoing specimens are six-armed; and further, one five-armed specimen from St. Paul's Island."

It seems probable that Stimpson's *A. acervata* is not specifically distinct from the North Atlantic and Arctic *A. polaris.* I have compared typical specimens of it with specimens of *A. polaris* from Labrador and found a close agreement, so that there can scarcely be a doubt of their identity, though they may be separated as geographical varieties. In that case the North Atlantic form should be called *Asterias acervata borealis* (Per.).

Stimpson's description applies fairly well to some specimens of the same size from the Atlantic, except in one particular. He mentions the occasional occurrence of stout, serrate major pedicellariæ in the lateral channels, evidently referring to the form characteristic of the various species of *Pisaster,* and also found in *Leptasterias epichlora alaskensis* Ver. and var. *subnodulosa* Ver. I have not been able to find such pedicellariæ on the Atlantic *A. polaris.* Therefore, it is not unlikely that some of Stimpson's specimens belonged to *subnodulosa,* which is also six-rayed and acervate and often has much resemblance to his *A. acervata.* Moreover, it is a very common littoral variety on the Alaskan coast, and Stimpson could hardly have failed to have had it in his possession. But in other respects his description certainly does not apply to the latter.

ASTERIAS KATHERINÆ Gray (*non* Perrier).

Plate LI, figures 1, 2; plate LII, figure 1 (dorsal, large); plate LXXXIII, figure 1 (details).

Asterias katherinæ GRAY, Annals and Mag. Nat. Hist., VI, p. 179, 1840; Synopsis, Genera and Species, p. 2, 1866 (*non* Perrier, 1875).

Asteracanthion katherinæ MÜLLER and TROSCHEL, Syst. Aster., p. 19, 1842 (translation from Gray). Dujardin et Hupé, Echinod., in Suites à Buffon, p. 339, 1862 (translation).

Gray's brief description of *A. katherinæ* is as follows:

"Rays six or rarely five, nearly three times as long as the width of the body; back with scattered and crowded, blunt, rough-tipped spines." He placed it in his section having the adambulacral spines crowded "as if two- or three-rowed," with the back "netted," ventral spines in two or three rows; lateral spines in a single row. He gave the locality as "mouth of the Columbia River, Lady Katherine Douglas."

To this species, long misunderstood and little known, I refer with confidence a good specimen obtained by Mr. A. Agassiz in the Gulf of Georgia, about 1860 (No. 1181, Mus. Comp. Zoöl. See plates LI, LII.) It agrees in all respects with Gray's brief description.

Rays six, moderately stout, evenly convex above and regularly tapered; larger radius, 85 mm.; shorter, 18 mm.; ratio, 1 : 4.72.

The dorsal spines are very numerous, mostly rather small, none large. Smaller ones clavate; larger ones somewhat capitate; arranged crowdedly without any regular order, but reticulate or in short rows in many places, both on the disk and rays, not acervate and not conspicuously diverse in size, though many on the transverse ossicles are quite small. The median dorsals are like the rest and do not form an evident row.

The superomarginals are a little longer and more cylindric, obtuse or slightly clavate, placed in a regular row, one to each plate.

The inferomarginals are quite similar and stand mostly one to a plate, but occasionally there are two to a plate.

The interactinal spines are shorter and stouter than the marginals, cylindric or slightly clavate, obtuse or pinched at the tip, nearly smooth. They form two close rows, or three in some places, proximally, crowded between the inferomarginals and adambulacrals, with very small papular areas around and between them.

They apparently stand on two close rows of interactinal plates, for there are small papular pores between the rows. The subactinal row extends in most cases only about half the length of the ray.

The adambulacral spines are unusually numerous, crowded in three or more rows. They stand mostly two on a plate, but often there are three on part of the plates, or alternately two and three. They are of moderate length, the outer ones longer, terete, slightly clavate, obtuse; the inner ones shorter, acute. Oral spines stouter, a little curved.

The minor pedicellariæ are very small and form small wreaths on the dorsal and superomarginal spines. The major pedicellariæ are very numerous and small, ovate, those on the dorsal side are unusually small and thickly scattered over the dermal areas. On the ventral spines they are little larger and more acute, numerous on the spaces between the actinal and marginal and adambulacral spines, and also form clusters on the spines. Those on the lateral areas are rather larger and more lanceolate, but still smaller than in most species. All the papular areas are small. The madreporic plate is large, with very numerous gyri.

Gulf of Georgia (A. Agassiz, 1860, Mus. Comp. Zoöl., No. 1181).

This species, as here described, resembles *A. borealis* in form, but it has smaller and more numerous dorsal spines, not acervate, and the actinal and adambulacral spines are more numerous and more crowded. The pedicellariæ are also different.

M. Perrier (1875, p. 332) stated that he found in the British Museum a number of specimens, some of which probably were Gray's types (though the label was loose). Most of these were six-rayed and monacanthid, but two were five-rayed. With them was also a single specimen of a six-rayed diplacanthid species that Perrier referred to *A. douglasi*, which last Bell, Perrier (1881), and Ludwig (1900) referred to *A. polaris* = *borealis*.

It is evident that Gray's name must be applied to a *diplacanthid* species, not to the monacanthid species to which Perrier restricted it, and which I have named *A. grayi*. If it were really certain that the specimens found by Perrier were Gray's cotypes, the name should be applied either to the six-rayed one called *douglasi* by Perrier, or to the five-rayed specimens referred to by him. But as the label was loose, it may well have been misplaced in the long interval of time (thirty-five years), or other specimens may have been added to the original lot. Such accidents happen in all museums. It is not unlikely that the *douglasi* Per. of the British Museum lot is the same as the species described by me as *katherinæ* above.

If *A. douglasi*[1] be really identical with *A. borealis,* as some claim, and that particular specimen, seen, but not described, by Perrier, is the same, it could hardly have been from the mouth of the Columbia River, as stated by Gray; for *A. borealis* (or *acervata*) has not been found on the northwest coast south of the Aleutian Islands by any of the numerous recent expeditions to that coast, so far as I know. On the other hand, the monacanthid, six-rayed species (*grayi* V.) belongs to a group of allied species well represented in Puget Sound and southward, so that the locality given by Gray might be right for that one. What his five-rayed specimens were I do not know; possibly they were *E. troschelii.*

ASTERIAS MULTICLAVA Verrill, sp. nov.

Plate LVIII, figure 2; plate LIX, figure 1 (large, actinal); plate LXIX, figure 1; plate LXXXIV, figures 2, 2*a* (details).

?? Asterias camtschatica BRANDT, Prod., p. 270, 1835 (description insufficient, perhaps *A. epichlora,* six-rayed var.). ? Stuxberg, Evert. Fauna Sib. Is., p. 28, 1880. Sladen, Voy. Chall., p. 820, 1889. Ludwig (*pars*), Fauna Arctica, I, p. 485, 1900 (distribution).

?? Asteracanthium camtschaticum BRANDT, in Middendorff, Reise, II, p. 32, 1851. ? Grube, Nova Acta Acad. Cæs. Leop., XXVII, pp. 23, 26, 1857 (*Asteracanthion*).

Rays six, rather long and tapered; disk small; radii, 14 mm. and 62 mm.; ratio, 1:4.4. Dorsal and ventral spines short, clavate, and capitate, very numerous, arranged largely in distinct radial bands. The dorsal spines are all similar in form and not very diverse in size. They form three or five crowded rows, with some scattered between; the median row is a little more conspicuous and its spines are crowded and a little clustered in many places. Those of the disk form many small clusters, but are not acervate; a circle of the smaller ones surrounds the madreporite. The superomarginal row is regular and compressed, having either two or (in the adult) three capitate spines to a plate. The inferomarginals are longer, stout, clavate, and stand either one or two to a plate, according to the age. The peractinals are similar, and stand mostly one (in the young), but often two (in the adult), to a plate; there is also a short subactinal row, and a short proximal, intermarginal row of small spines. Thus in the adult the lateral and interactinal spines are unusually

[1] The types of *A. douglasi* are, apparently, the five specimens, without locality, preserved in the Paris Museum. The British Museum specimen may not have been identical, but really Gray's type, from off the Columbia River.

numerous as well as the dorsals. In two small specimens, with the larger radii 24 mm. and 28 mm., the inferomarginal and the peractinal rows are single, but the superomarginal rows are double. The spines in these are less clavate. The adambulacrals are irregularly diplacanthid; distally they are slender and subclavate, obtuse; proximally they become much more slender, longer, tapered, subacute. They have large clusters of minor pedicellariæ, with some small major pedicellariæ intermixed. Small clusters of minor pedicellariæ are also found on the lateral and dorsal spines. Dermal major pedicellariæ of small and moderate sizes are numerous between the lateral rows of spines. They are ovate and ovate-lanceolate in form, and subacute; others, much smaller and mostly ovate, are found with them and also on the dorsal surface. The papular areas are small. Color in life: "Above, deep olive green with the tips of the spines whitish; those of the edges very pink" (Stejneger). The type (No. 15841, U. S. Nat. Mus.) was taken February 2, 1883, at Bering Island, Commander Is., by Dr. L. Stejneger. Three smaller specimens are from Petropaulski, Siberia, *Albatross* collection.

This species is evidently related to *A. acervata borealis.* It differs mainly in the pretty regular arrangement of the dorsal spines in three or five multiple rows; in having the superomarginal rows of plates double- or triple-spined, and the inferomarginals and peractinals double-spined when adult. These features I have not seen in the Atlantic *borealis,* nor in the Pacific form, *A. acervata.* The young specimens resemble some species of *Leptasterias,* like *L. dispar.*

The species very imperfectly described by Brandt, from Siberia, has always been doubtful, Ludwig considered it the same as *A. acervata* Stimpson (see p. 110), but that does not seem very probable. It is more likely to have been this species, if either.

Brandt's original description was based on a colored drawing of a very young specimen ("diameter of disk, one inch; length of rays, one to one and one-fourth inches").

Aside from the size and color, the only other characters given are that the dorsal spines ("papillæ") are numerous and "truncate-capitate," reticulate, and form "subangular* series" on the rays. The last statements do not apply very well to *A. acervata,* but would apply very well to this species, and also to some of the six-rayed varieties of *epichlora.* But the latter is not known to me from the Arctic Ocean nor from Siberia.

The capitate form of the larger spines is characteristic of all these forms, as well as many others.

On the whole, especially considering the locality, it is more probable that Brandt's original type of *A. camtschatica* was the same as the present species; but the description is so indefinite and vague that it seems unsafe to use his name, for the species of this group are very numerous.

Genus **Leptasterias** Verrill.

Leptasterias VERRILL, Proc. Boston Soc. Nat. Hist., x, p. 350, 1866. Type, *L. mülleri* Sars. Sladen, Voy. Chall., xxx, p. 563, 1889. Perrier, Exp. Trav. et Talism., p. 108.

An extensive group of small, more or less diplacanthid starfishes, closely related to typical *Asterias,* usually with a single row of interactinal plates and spines. Rays five or six. The more typical forms have slender rays and a small disk, with the dorsal ossicles irregularly arranged; others have several subimbricated radial rows, with clustered spines. It differs especially from typical *Asterias* in the diminished number and larger size of the dorsal and lateral papulæ, and the small number of interactinal plates, of which there is generally only a single row. The eggs and young are carried in clusters, adhering in front of or around the mouth in most if not all the species. The genital pores are on the actinal side, near the mouth. The oviduct is wide and short; the ovarian tubules are few, thick, beaded by the eggs. (See also p. 8). Type, *L. mülleri* (Sars).

The most abundant species of Alaska (*L. epichlora*) is by no means a typical member of this group, for in many respects it is intermediate between it and typical *Asterias,* especially in having larger clusters of papulæ and often two proximal rows, or sometimes three, of interactinal spines when of large size.

The species of this group are remarkably variable in many cases. This is particularly true of those inhabiting the vast extent and varied localities of the Northwest coast.

This unusual tendency to form marked, more or less localized varieties is, like the same phenomenon seen in the genus *Henricia,* probably due to the fact that most, if not all, of the species of these genera carry their young, until they reach the starfish form, attached to the region about the mouth, and consequently have no free-swimming larval stages (*brachiolariæ*), such as we find in the species of typical *Asterias.* The free-swimming young of the latter may remain afloat many days, or even weeks, and thus they may be carried long distances by the currents, in one generation, or they may be scattered in different directions over large areas, thus mixing up the young from various localities.

On the contrary, the sessile condition of the young in the species of *Leptasterias* insures greater safety, and though the eggs are much fewer in number, a far greater per cent will reach maturity.

This method of propagation precludes the rapid diffusion of such species, for they can only migrate by means of the slow method of creeping by the use of their ambulacral feet, unless accidentally carried, attached to floating objects. Under these conditions any local variations that may arise, unless harmful, are likely to be perpetuated by inheritance and isolation. As a matter of fact, many such varieties are already known, some of which may be quite localized, so far as known, while others, probably of much earlier origin, are diffused from Puget Sound to the Aleutian Islands.

Very extensive collections along the whole coast are needed before the real status of many of the varieties in this group, as well as in *Henricia* and *Pteraster*, all of which carry their young, can be settled.

Our present collections are quite inadequate. The most that we can now do is to describe and figure those varieties that we happen to obtain and that seem worthy of recognition.

It is not to be supposed that they will be found constant, nor that intermediate forms will not occur. That coast seems to be one vast nursery for new varieties and subspecies.

Some of the odd forms are probably hybrids between distinct species, but at present there is no way to determine this. Some of the forms classed in *Leptasterias* may eventually prove to be the young of larger species of *Asterias* proper, for the latter all pass through a *Leptasterias*-like stage in the course of their growth. It is impossible, in many cases, to distinguish these young forms without larger series of intermediate sizes. The only positive criterion, in many cases, would be the position of the genital pores and the incubation of the young, which have not been observed in many species.

LEPTASTERIAS (?) INEQUALIS Verrill, sp. nov.

Plate LXXIII, figure 2; text-figures 4, 5.

The type is a small five-rayed starfish with depressed, rapidly tapering and rather acute rays. Radii, 7 mm. and 26 mm.; ratio, 1 : 3.71.

The dorsal ossicles are lobate, numerous, mostly flat and closely united, leaving small papular areas, and not distinctly reticulate in arrangement. The larger plates in the median and intermediate rows are convex and more prominent. The apical plates are smaller than in *epichlora* of the same size; hence the rays are more acute. The

dorsal spines are very unequal in size and form. Those on the median radial rows, and in the incomplete, short, intermediate series, are much larger than the rest, about as broad as high, with round capitate tips. They mostly stand singly, but often two to a plate. Large numbers of very much smaller, unequal, minute spinules are thickly scattered over the surface, but not crowded. These stand singly or in small groups on the smaller, intermediate ossicles. Each spine is surrounded by a circle of minor pedicellariæ, nearly as large as the smaller spines. These small spines are slender, two or three times as long as thick, terete or slightly clavate, obtuse, partially concealed by the wreaths of pedicellariæ.

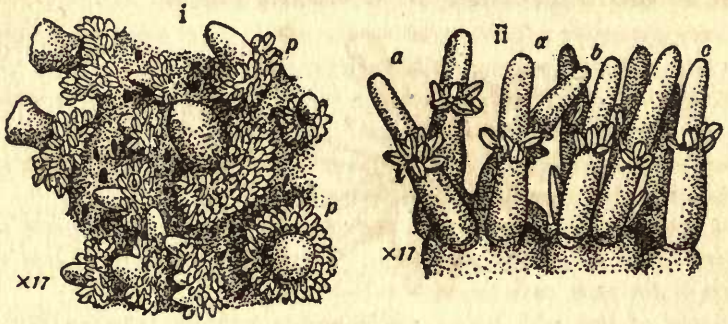

FIG. 4.

Leptasterias inequalis V. type. i, Portion of the dorsal surface showing spines of diverse sizes, wreaths of minor pedicellariæ, and papular pores. × 17. ii, The same; *a*, *a'*, adambulacral spines and epispinal pedicellariæ; *b*, double row of interactinal spines with epispinal pedicellariæ and major pedicellariæ between their bases; *c*, inferomarginal spines with epispinal pedicellariæ.

The disk is covered with numerous scattered, unequal spines, which do not form very evident circles around the madreporic plate. The latter is small, with fine gyri, and not very far from the center.

The upper marginal spines are decidedly longer than the median and slightly tapered, obtuse or subacute; they form a regular single row.

The inferomarginals and interactinals are a little longer, more slender and less obtuse. The inferomarginals and peractinals each form a single continuous row, the spines becoming shorter and more obtuse distally. The subactinal row extends to about the middle of the ray. The lateral channel between the two marginal rows is narrow but very distinct.

The adambulacral spines are about as long as the peractinals, and nearly as large. They are terete, often a little thinner in the middle and slightly enlarged toward the obtuse or subacute tips; those

towards the mouth are distinctly longer, more slender, and more acute. The mouth is not much sunken and the adoral carinæ are short, composed of only two contingent pairs of plates, besides the epiorals. The apical pairs of peroral spines are well developed, but shorter and not stouter than the average adambulacrals; the side spine is about half as long, strongly divergent, so that those on adjacent jaws often have their tips in contact and thus might form a continuous fence around the oral area. The epiorals and adorals are long and slender, tapered, subacute; they often bear both minor and major pedicellariæ. The latter are small, ovate-lanceolate, subacute. Minor pedicellariæ are abundant on all the spines, forming close wreaths on the dorsals and superomarginals, but secund clusters

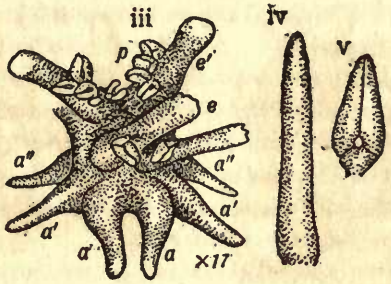

FIG. 5.

Leptasterias inequalis. iii, One of the jaws, *a*, *a*; *a'*, *a'*, apical or peroral spines; *a''*, lateral jaw-spines; *e*, the first pair of epioral or suboral spines; *e'*, 2d pair; *p*, pedicellariæ; × 17. iv, One of the adoral spines; × 17. v, A major pedicellaria more enlarged.

on all the spines of the lower surface. Major pedicellariæ are few in number, small, ovate or ovate-lanceolate.

The type is from Orca, Alaska (Prof. W. R. Coe, Harriman Expedition).

This is, quite probably, the young of a larger species, perhaps not a *Leptasterias,* but I am unable to refer it to any known to me. It somewhat resembles some of the five-rayed varieties of *epichlora,* but the flat, closely imbricated dorsal ossicles, without many reticulations, forbid its union with that protean species, at present, for no intermediate specimens have been found.

LEPTASTERIAS LEPTALEA Verrill, sp. nov.

Plate XVIII, figure 3 (type).

A small and very delicate five-rayed species. Radii, 2.5 mm. and 15 mm.; ratio, 1:6. Rays terete, evenly tapered. Dorsal ossicles relatively strong, thickened, especially those in the median rows.

Dorsal spines not numerous, conical, relatively stout, usually standing singly, one to an ossicle, and forming three or five rather irregular rows. Ocular plate relatively large, bearing a dense cluster of small spines. Minor pedicellariæ of unusually large size and with strongly curved blades are usually numerous in groups around the dorsal spines and on the papular areas. Adambulacral spines mostly two to a plate, or alternately one and two distally, very slender, terete, often slightly clavate. Lower marginal spines, which are much larger, acute, conical, like the dorsals, but longer, form a single row next the adambulacrals, or there may be two to a plate, proximally, in the larger specimens. The synactinal plates appear to be few and small, or altogether lacking in our examples, but may occur in larger ones. Upper marginal spines form a single row and resemble the dorsals in form and size. Major pedicellariæ few, small, ovate.

The ambulacral feet are in four rows, but the adjacent rows form only a zigzag line, so that they sometimes appear almost biserial.

This species looks very much like a *Pedicellaster,* not only in size and spinulation, but also in the character of the pedicellariæ. The arrangement of the ambulacral feet in four rather indistinct rows forbids its place in that genus, however.

Our specimens are evidently not full-grown, but it probably never becomes large, perhaps not more than 50 mm. in diameter.

Virgin Bay, Alaska (W. R. Coe).

It is more delicate than the Atlantic *L. tenera,* of the same size, but has larger dorsal spines, much fewer in number, and the dorsal pedicellariæ are much larger and different in form. The much smaller number, larger size, and isolated position of the dorsal spines indicate that it cannot be the young of *C. cribraria* or *L. hexactis.* The young of the latter, of similar size, are known to me, and are very different.

LEPTASTERIAS ARCTICA (Murdoch).

Plate LVI, figures 1, 2 (young); plate LXXI, figures 1, 2; plate LXXII, figure 1; plate LXXXIII, figures 2, 2*a* (details).

Asterias arctica (Murdoch), Report of the International Polar Expedition to Point Barrow, Alaska, under Lieut. Ray, 1885, p. 159.

Mr. Murdoch's original description is as follows:

"Rays five, rounded above, elongated, tapering regularly to the tips. Radii as 1 : 3.5. Disk small, its radius about equal to width of ray at base. Interambulacral spines round and slender, with rounded tips, usually two to each plate. No small spines between

these and the ventral spines. Ventral spines (inferomarginals) form a double row of alternating spines, of which the upper are the smaller and the lower are larger and stouter than the interambulacrals. Lateral spines (superomarginals) rather slender, forming a single row. No well marked dorsal row, though the spines in the middle of the arm are rather the larger. The dorsal spines are short and stout, with rounded, almost capitate tips. The spines of the disk are rather smaller than those of the arms and are arranged irregularly. The major pedicellariæ could not be well made out, but appeared to be lanceolate and not numerous. The minor pedicellariæ form close wreaths around the spines."

I have examined the types of this species, which are preserved in the U. S. National Museum, and also a number of other lots from the same region.

The larger type-specimen, dried from alcohol (*a*), has the radii, 7 mm. and 32 mm.; ratio, 1 : 4.57. A smaller one (*b*) has the radii, 5 mm. and 23 mm.; ratio, 1 : 4.60. But it becomes considerably larger than these. One of the larger ones from Arctic Alaska (No. 1428, Mus. Comp. Zoöl., pl. LXXI), has the radii 11 mm. and 44 mm.; ratio, 1 : 4.

This species varies somewhat in the size and number of the dorsal and marginal spines and also in the form and size of the adambulacral spines, and especially in the number of minor pedicellariæ. The general appearance is somewhat like that of *L. compta,* of the New England coast, but the forms of the spines are coarser and the pedicellariæ are different.

In most cases, including the type-specimens (*a* and *b*), there is an evident, but crooked, median radial row of distinctly larger spines, when dry. The other spines are rather numerous, irregularly scattered, and reticulated, but often forming indistinct longitudinal rows, as well as occasional short transverse series proximally on the sides of the rays. They are all short and blunt, not minute. The larger ones are about as high as broad, somewhat capitate, with finely striated and evenly rounded tips; the smaller ones are more or less clavate or subcapitate. All the dorsal and marginal spines are usually surrounded by dense clusters of very small minor pedicellariæ, which in alcoholic specimens are attached to a sheath that usually rises to mid-height of the spine, and in the case of the inferomarginal spines, it frequently nearly reaches the tip, and thus the dense clusters of pedicellariæ often conceal the tips of the spines and are nearly or quite in contact with each other. But some specimens,

of small or moderate size, have only very small clusters of pedicellariæ, and these may be seen only at the base of the spines, especially when dry, the sheath being rudimentary or contracted; or they may be lacking on many of the spines in young specimens.

The superomarginal spines are much like the dorsals in size and form, and therefore not easily distinguished in many specimens, but they are usually slightly longer. In most specimens of average size there is a short proximal row of more slender spines interpolated between the upper and lower marginals.

The inferomarginal spines are decidedly longer and larger than the upper ones, often being twice as stout. They are usually terete, scarcely tapered, often slightly curved and obtuse. Frequently they stand two to a plate; the upper ones are smaller; but in many cases they stand singly, in a regular row. The larger specimens usually have a short proximal row of interactinal spines, similar to the inferomarginals. This is true of the larger of Mr. Murdoch's type-specimens. The adambulacral spines stand one or two to a plate in irregular alternation. They are nearly as long as the inferomarginals, usually much more slender, terete and blunt, sometimes slightly clavate, but in some cases they are stouter than usual and nearly as large as the inferomarginals. They usually bear clusters of minor pedicellariæ, and many isolated major pedicellariæ.

The apical peroral spines are usually rather large and strong, being considerably stouter than the adorals. The epiorals are also rather stout and distinctly longer than the adorals.

Major pedicellariæ are sometimes few in number, but usually there are many of rather small size attached within the margin of the grooves, and some of larger sizes on and between the adambulacral spines and oral spines. Some of the larger kind also occur on the interradial areas and lateral channels. They are mostly compressed, ovate-lanceolate or oblong-lanceolate, with acuminate tips. The larger ones are often as stout as the adjacent adambulacral spines, and these usually have dentate tips.

Mr. Murdoch described the same specimens, as preserved in alcohol, hence he overlooked some of the details, obvious when dry.

Two young specimens, which I refer doubtfully to this species, were collected by Dr. W. H. Dall on the coast of East Siberia, at East Cape (U. S. Nat. Mus., No. 6031).

Others, similar, were collected in Bering Strait by Robt. White (No. 16591. Pl. LVI. figs. 1, 2.) The radii of the largest are 3.5 mm. and 11 mm. The dorsal spines are small, clavate, arranged

in three radial rows, those in the median one largest. The two marginal rows are regular and distinct, the spines being longer, regularly spaced, one to each plate. Actinals mostly lacking. Adambulacral spines slender, subdiplacanthid. Minor pedicellariæ are present in small clusters on most of the spines, but form complete wreaths on the upper marginals. One of these young specimens was labelled, by Dr. Dall, as white when living.

Arctic Ocean, off Point Franklin, in thirteen and one-half fathoms, sand (coll., Murdoch, Point Barrow Expedition), types (three), No. 7625, U. S. National Museum; Arctic Ocean, ten fathoms (Dr. W. H. Dall), No. 3622 (1669), U. S. National Museum; Bering Straits (Robt. White), No. 16591; East Siberia, Nos. 6031 and 16584 (young) (W. H. Dall).

Several young specimens (Nos. 16584) from ten to fifteen fathoms, Plover Bay, Siberia, probably of this species, are nearly or quite monacanthid. The larger have radii 5 mm. and 15 mm. The dorsal spines are unequal, not crowded, the larger are short, capitate; all are surrounded by pedicellariæ in wreaths, unusually abundant for so young specimens. Papulæ are mostly isolated; dermis thick.

LEPTASTERIAS COEI Verrill, sp. nov.

Plate IX, figure 1; plate XVII, figures 1, 2 (types).

A slender species, usually six-rayed. Disk small; rays long and neatly rounded, tapering gradually. Radii, 5 mm. and 30 mm.; ratio 1:6, sometimes less.

The dorsal spinules form three pretty regular primary rows, with many smaller ones scattered between irregularly, but not crowdedly, and not clustered. Usually the spines stand singly, one to a plate; the median radial ones are larger and form a pretty regular row. All are cylindrical or slightly clavate, of moderate length, with rounded tips, and are surrounded by small dense wreaths of minor pedicellariæ, which are nearly in contact in alcoholic specimens.

The upper marginals are a trifle longer and form a regular row, one to a plate. The lower marginals are rather longer, terete, mostly one to a plate, but sometimes with a second smaller one proximally. An imperfect row of somewhat smaller synactinal spines proximally. The adambulacral spines are mostly in two equal rows, but some of the plates bear only one spine; these spines are slender, terete, tapered, subacute, nearly as long as the lower marginals, but much more slender; they bear small groups of minor

pedicellariæ. A few small, long-ovate, compressed major pedicellariæ occur on the actinal interradial areas and along the edges of the grooves. The papulæ stand singly or in groups of two to four. Madreporic plate small, prominent, with few gyri, pale orange in alcohol.

A smaller specimen (pl. IX, fig. 1; pl. XVII, fig. 2), taken at the same place, was also preserved in alcohol. The dorsal spines already form five distinct rows, with others between them; the median row is conspicuous and its spines much larger than the others, with rounded tips. Wreaths of minor pedicellariæ are much smaller and not in contact generally. Lateral and ventral spines longer and in very regular rows. Madreporic plate is pale orange in alcohol. In life the color was uniform iron-rust color (Coe).

The types described are from Berg Bay, Alaska, in ten fathoms (W. R. Coe, Harriman Expedition, June 10, 1899).

This species bears a general resemblance to *L. tenera* (St.) of the New England coast, but the dorsal and marginal spines in the latter are far more numerous, much smaller, and acute; it very rarely has six arms, and its dorsal ossicles are much more numerous. Typical specimens of *L. mülleri* from Greenland are still more closely allied, but the latter is a five-rayed species, and also has more slender spines (though not so slender as in *L. tenera*), and has fewer pedicellariæ, somewhat different in form.

LEPTASTERIAS MACOUNI Verrill, sp. nov.

Rays six, elongated, slender, rounded and evenly tapered. Radii, 8 mm. and 41 mm.; ratios, 1 : 5. Dorsal ossicles thick but small, with large papular pores between them; median row thicker, forming a slight carina; others reticulate. Dorsal spines slender, small, scattered or in several obscure rows, except the median radial row, which is distinct, consisting of small clavate spines, mostly standing two to a plate, in nearly simple lines. Similar spines cover the disk. The larger intermediate dorsal spines are rather smaller, slender, tapered, subacute, mostly one to a plate, arranged somewhat in quincunx, or in about three irregular rows on each side, the larger papular areas forming oblique rows of three on each side. Some minute spines stand on the transverse ossicles.

Superomarginal spines distinct, larger and longer than dorsals, obtuse or a little clavate, forming a simple regular row. Inferomarginal spines are of similar length or a little longer, subacute, mostly two to a plate, forming two alternating rows.

Interactinal spines are similar to the inferomarginals and form three simple oblique rows proximally, one spine to a plate, there being three rows of small, thick interactinal ossicles separated by rows of small papular pores. The peractinal row reaches nearly to the tip of the ray; the next one reaches to about the middle; while the third is confined to the basal part of the ray. All these rows bend upward pretty regularly proximally.

Adambulacral spines slender, tapered, obtuse, much smaller and shorter than the interactinals, subdiplacanthid, part of the plates bearing one, and part two spines in irregular alternations. Oral spines have been destroyed in the type.

Small wreaths of minute minor pedicellariæ surround most of the dorsal spines; major pedicellariæ few and small. Madreporite small, fine-grained, surrounded by a circle of small clavate spinules.

The type was taken at Departure Bay, Vancouver Island, on rocks at low tide by Prof. John Macoun and party, of the Canadian Geological Survey, 1909 (No. 43). It is dedicated to Prof. John Macoun. I have seen no others.

This species most resembles *L. hexactis* in general appearance, but the latter has the dorsal spines clustered and has fewer rows of actinal plates and spines. It may eventually prove to be a variety of *hexactis*, when a larger series can be studied. I have seen no intermediate specimens.

LEPTASTERIAS VANCOUVERI (Perrier).

Asterias vancouveri Perrier, Arch. de Zool. Expér., IV, p. 328, 1875. Bell, Trans. Zoöl. Soc. London, pp. 496, 504, 1881. ?=*A hexactis* Stimpson.

No specimen perfectly agreeing with this small diplacanthid species has come under my observation.

According to the imperfect description of M. Perrier, it somewhat resembles, in form and ornamentation, *Asterias* (*Stichaster*) *polyplax*. Arms six or seven. Adambulacral spines long, pointed, two upon each plate, but not in two regular rows, the rows irregularly alternating; each bears on the middle one or two small major pedicellariæ. Outside of these are two rows of pointed ventral spines, larger than the adambulacrals and surrounded by a few minor pedicellariæ. Ossicles of the dorsal skeleton much as in ordinary species of *Asterias*. On the back are five ranges of groups of small obtuse spines, each ossicle bearing a group of three or four spines; other spines are borne on the transverse connecting ossicles, so that the groups of spines appear confluent and form a vague reticulation.

Madreporic plate single. Diameter of disk, 10 mm.; distance between ends of the two arms, 75 mm.

Vancouver Island (British Museum).

This small species, to judge from the brief description, should be closely allied to, or identical with, *L. hexactis,* of earlier date. The description, at least, would apply to that species. The types of the latter, moreover, were from the same region (Puget Sound). No other similar six-rayed species has been found by me in any of the large collections recently received from Vancouver Island.

It must also resemble some of the more slender six-rayed varieties of *L. epichlora,* but the latter does not often occur in my Vancouver Island collections, and has much more numerous actinal spines.

LEPTASTERIAS HEXACTIS (Stimpson).

Plate xxv, figures 7, 8 (type).

Asterias hexactis Stimpson, Proc. Boston Soc. Nat. Hist., viii, p. 272, 1862. Verrill, Trans. Conn. Acad. Sciences, i, p. 326, 1867. Bell, 1881, p. 495.

This is a small six-rayed starfish, much like *L. æqualis,* but with the dorsal spinules longer, slender, less numerous, and not so closely clustered. The rays are usually longer and more tapered.

Dr. Stimpson's description was as follows:

"Rays six, depressed or rounded, and more or less tapering. Disc large. Proportion of the diameters, 1:4. Ambulacral spines, subequal, in two regular rows towards the disc, two to each plate;—form cylindrical, obtuse, sometimes a little clavate, with a few pedicellariæ of both kinds on their outer side at the middle. On the latero-inferior side of the ray there are four longitudinal rows of spines, separated from the dorsal spines by a more or less well marked channel. These spines are scarce thicker than the ambulacrals, but are longer, and have small clusters of minor pedicellariæ at their outer bases. In some specimens the lateral spines are distinct from the ventrals, being separated from them by a channel, and forming a crowded row of confluent clusters like the dorsals. Dorsal spines small and numerous, in little heaps, which, being confluent in a longitudinal direction, form three or five (according to the distance from the disc) rows, separated from each other by corresponding rows of papuliferous depressions. These spines in some specimens, however, are fewer, and do not form heaps. On the disc they are arranged after a reticulating pattern. The spines are capitate, and sparsely surrounded by minor pedicellariæ. All rise to about the same height, thus giving an evenness to the outline as seen in a side view. The

major pedicellariæ are few, and formed on the labial spines, or rarely a single one on the side of the ray;—they are more or less pointed, about one-fortieth of an inch long, and twice as long as broad. Dorsal papulæ in small groups. Ventral papulæ mostly single, and curving upward or outward. Diameter, one and three-fourths inch. A variety occurs with more slender and tapering rays.

"It is smaller than *A. Camtschatica* Brandt, and has longer arms, etc.

"Habitat, Puget Sound. North West Boundary Commission. Dr. C. B. Kennerly."

A good dry specimen in the Yale Museum, from Monterey (Stevens), seems to agree pretty closely with the type. The radii are 5 mm. and 22 mm.; ratio, about 1:4.5. Rays six, slender, terete, tapered to acute tips. The dorsal spines, which mostly stand singly, sometimes two or three together, do not form definite rows. They are numerous, but not crowded, slender, slightly clavate, or subacute; they are surrounded by small wreaths of minor pedicellariæ, of relatively large size, which, in alcoholic specimens, fill up the spaces between the spines and give the surface the same even appearance as if the spines were more crowded. The upper marginal spines, which are nearly like the dorsals in size, though rather longer, form a pretty regular row; two often stand on one plate. The lower marginals are at least twice as large and long, and form a very distinct row, but two often stand on a plate; they are terete, tapered, subacute. The few synactinal spines, when present, are similar. Adambulacrals are nearly as long as the marginals, but are more slender and scarcely taper; they mostly stand two to a plate, divergently, and form two regular rows; they become distinctly longer near the mouth. The tip of each jaw bears two terminal longer and stouter spines, larger than the marginals, and a much smaller one external to these, on each side.

Major pedicellariæ of rather small size are borne, mostly singly, on many of the adambulacral spines, and much smaller ones on the inner margins of the grooves. They are compressed, long-ovate or lanceolate, subacute. They are larger, longer, and less triangular than those of *L. æqualis*.

A young specimen, 25 mm. in diameter, from Kadiak, Alaska (Harriman Expedition), appears to belong to this species. The six rays are very slender, and rather closely covered with very small obtuse and capitate spines, more or less areolated on the central parts. Adambulacral spines very slender, mostly in two rows. Its aspect is like that of a *Pedicellaster*.

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Dr. R. Rathbun has furnished, for reproduction here (pl. xxv, figs. 7, 8), photographs of the type, now in the U. S. National Museum.

San Francisco, California, to Sitka. A common littoral and shallow-water species. At Monterey it occurs associated with *L. æqualis*.

I have also studied numerous specimens from Puget Sound and Queen Charlotte Islands, sent by the Geological Survey of Canada.

This species has often been confounded with *L. æqualis* in collections. Though closely related, it can be distinguished by its different spinulation and distinct form of pedicellariæ.

LEPTASTERIAS ÆQUALIS (Stimpson).

Plate xvi, figure 8; plate xviii, figures 1, 2; plate xxv, figures 5, 6 (type); plate lvi, figure 5 (var.).

Asterias æqualis Stimpson, Proc. Boston Soc. Nat. Hist., viii, p. 273, 1862. Verrill, op. cit., p. 327, 1867.

As usually found, this is a small, six-rayed species. Disk small; rays rather short. Dorsal spines small, clavate or capitate, sulcate, and rough or spinulose at tip, very numerous, covering the whole upper surface nearly evenly, but sometimes forming indistinct median radial rows. A group or row of spines stands on each of the ossicles, which are small and numerous; they are rather closely imbricated, but leave papular areas, often as wide as the ossicles. Median ossicles larger, with rounded lobes, the proximal lobe longer and broader, imbricated. Marginal and actinal spines more elongated, forming several longitudinal rows, slender, subacute. Papular areas, on the upper side, form longitudinal rows; the papulæ stand singly or sometimes two or three together.

A good characteristic specimen of the California form (var. *æqualis*) from Monterey, the type locality, has the radii 6.5 mm. and 20 mm.; ratio, about 1 : 3.5. The rays are round and plump, tapering gradually.

The dorsal spines are very numerous, small, nearly equal and even, mostly capitate or clavate, with sulcate tips; they stand in groups of three to eight or more. Some of the groups are circular with a central spine, but others surround the papular pores, which have an evident longitudinal arrangement. The upper marginal plates form a crowded row, two to four spines standing together on most of the plates, while one or two usually stand on the descending lobe or connecting ossicle, proximally; these spines are slightly longer than the dorsals, and mostly bent upward, but are otherwise

similar. The lower marginal spines form a double row, two divergent spines usually on each plate; these spines are distinctly larger and longer than the dorsals, mostly compressed and somewhat clavate at the tip, and usually bent outward and upward. A single row of synactinal spines of similar size and shape usually occurs on the proximal part of the rays. Adambulacral spines are nearly as long as the actinals and about half as thick, terete, obtuse. On the basal half of the rays they stand two on a plate, forming two divergent rows; distally they are irregularly alternated, one and two; those near the mouth are longer. The tip of the jaw bears four divergent spines, the two central stouter but not longer than the adambulacrals, the other two much smaller and about half as long.

Major pedicellariæ of very small size occur singly on many of the adambulacral spines; these are short-ovate or triangular-ovate with acute tips. They are smaller, shorter, and more triangular than those of *L. hexactis*. Smaller ones also occur on the inner edges of the grooves. Major pedicellariæ of very small size occur singly or in small clusters on most of the dorsal and lateral spines, and in somewhat larger groups on the ventral ones. They also occur singly, between the spines, on the back.

Dr. R. Rathbun has furnished the photographs of the original type of this species, which is still in the U. S. National Museum. (Pl. xxv, figs. 5. 6.)

It agrees very well with several specimens in the Museum of Yale University, from the same locality. Stimpson's description is as follows:

"Rays six, rather slender and much tapering. Proportion of the diameters, 1 : 3.5. This species has a general resemblance to *A. hexactis* in shape, etc., but differs in the character of its spines, particularly the very numerous dorsals, which are uniform in size, and shorter and more crowded, giving to the back in a much greater degree that general evenness of surface which is characteristic of the *Stichasters* and *Cribrellæ* [*Henriciæ*]. These spines are deeply striated or radiated on their flattened heads, each showing eight or nine ridges. On the side of the ray there are two or three rows of longer spines, also striated. The ambulacral spines are for the most part arranged alternately one and two to each plate, but there are two to each plate near the disc. There are minor pedicellariæ about all the spines, as in the preceding species [*A. hexactis*], but they are much less numerous. We can discover no major pedicellariæ excepting an occasional small pointed one in the ambulacral furrows. They would

perhaps be found on the sides of the ray in specimens more perfect than those we possess. The papulæ stand singly or in groups of three or four, arranged in indistinct longitudinal rows. Diameter, one inch and a half.

"Habitat, Monterey, California. A. S. Taylor."

Common on the coast of California. Ranges from San Diego north to Puget Sound and Vancouver Island. Monterey (Stimpson; Stevens; R. E. C. Stearns).

This species is not a typical *Leptasterias*. It differs from most species of that genus in the apparent longitudinal or "stichasterial" arrangement of dorso-lateral plates, and in having the minute spines closely clustered on the plates, much as in *Stephanasterias* and in *Henricia*, so that its appearance is superficially like one of the Stichasterinæ. However, its dorso-lateral plates are not so wide, nor so closely imbricated, as in that group, nor even so much so as in *Stenasterias*. Its genital pores and reproduction are not known.

This species varies considerably in its form and spinulation. I have examined numerous specimens from Monterey, the type locality, collected by several different persons. It seems to be very abundant on that part of the coast, between tides.

Owing to its variability it may be divided into several varieties or local races, though these doubtless intergrade at intermediate stations.

The rather dwarf littoral form from California is certainly the original or type-form, and should therefore be designated as variety *æqualis*, if varieties be recognized.

LEPTASTERIAS ÆQUALIS Var. COMPACTA Verrill, nov.

Plate LVI, figure 5.

The type of this form is much larger and more fully developed than the ordinary littoral varieties. The radii are 15 mm. and 45 mm.; ratio, about 1 : 3.

The six arms are evenly rounded above and densely covered with small capitate spines standing in large clusters on each ossicle. They form a distinct, wide, median band, and two other similar bands on each side are defined by the rows of papular pores. The dorsal ossicles are in five rows, strong, elevated in the middle, closely united in rows and somewhat imbricated, especially in the median row. A close circle of small capitate spines, like the dorsals, surrounds the madreporic plate, which has numerous fine irregular gyri. The

upper marginal spines are numerous, similar to the dorsals, but rather longer; they stand in oblique clusters on each ossicle. Besides the main row, there are two to four similar spines on the descending apophysis, and on a small connective ossicle, sometimes present, forming an interpolated series between the upper and lower marginals on the basal half of the rays.

The longer ventral spines form three main rows, besides a few irregular smaller ones.

The inferomarginal plates are closely united and each usually bears two cylindrical or slightly clavate, blunt spines, decidedly longer and larger than the dorsals; or sometimes three near the base of the rays, besides one or two smaller ones. The actinal spines form a single row, one to a plate, and do not extend to the tips of the rays; they are sometimes lacking.

The adambulacral spines stand two on a plate, but not in regular lines; they are shorter and more slender than the actinals, but similar in form.

The superomarginal ossicles are stout, thick, and imbricated, strongly four-lobed. The upper lobe is large and runs slightly obliquely outward; the large lower lobe or apophysis is elevated in the middle, where it bears several intermediate spines, or it may be overlapped partially by a small interpolated ossicle. There is a row of small papular areas between the apophyses. The inferomarginals are also stout, but smaller, with four short lobes. The actinal plates, near the base of the rays, are smaller, irregularly elliptical, and closely united to the adambulacrals. The apex of the jaws bears a pair of stout peroral spines and a pair of divergent lateral ones, about half as long. On the outer surface of the jaw there are usually one or two pairs of epiorals that are longer and more tapered than the following ones. The ambulacral grooves are unusually wide; the plates not very crowded; the pores large, not crowded. Dorsal papulæ few, in small groups or isolated.

Minor pedicellariæ are very small and occur on nearly all the spines in small groups or singly. Major pedicellariæ, of very small size, acute-triangular in form, occur along the inner edges of the ambulacral grooves.

Pacific Grove, Monterey, California (Prof. W. R. Coe); British Columbia.

This may be regarded as the most perfectly developed variety of *L. æqualis*. Its characters are probably in part due to its large size, but I have seen others of the same variety not over an inch in diameter.

LEPTASTERIAS ÆQUALIS Var. NANA Verrill, nov.

This name is proposed for a common, rather dwarfed variety, having short obtuse rays, rather densely covered with small, short, nearly even, obtuse or clavate spinules.

The inferomarginal and actinal spines are crowded together and form about four close rows.

Common on the California coasts; Gulf of Georgia.

LEPTASTERIAS ÆQUALIS Var. CONCINNA Verrill, nov.

This name is proposed for a larger form of this species, in which the dorsal spinules form large groups on the ossicles, and these lie in pretty regular longitudinal rows, three or five, separated by very distinct rows of papular areas. The larger marginal spines also form very regular rows.

The type is from Monterey Bay, California.

LEPTASTERIAS EPICHLORA (Brandt).

Plate XVI, figures 1-6 (varieties); plate XXVIII, figures 1, 2 (variety); plate LXXXV, figures 1-1*d* (details), figures 2-2*e* (young).

Asterias epichlora BRANDT, Prod. Descr. Anim. Mertens, p. 270, 1835. (Five-rayed form. Description poor.) ? Stimpson, Journ. Boston Soc. Nat. Hist., VI, p. 528 (excel. synonyms). Perrier, Révis. Stell., p. 331 (no description).

? Asterias camtschatica BRANDT, Prodromus, p. 270, 1835; Middendorff Reise, II, p. 32, 1851. (Six-rayed form.)

Asterias saanichensis DE LORIOL, Mém. Soc. Phys. et Hist. Nat. Genève, XXXII, p. 23, pl. II, figs. 3-3*d*, 4, 5, 1897. (Five-rayed variety.)

A rather small starfish, commonly 60 mm. to 80 mm. in diameter, sometimes 150 mm.; usually greenish or olive on the dorsal surface in life; generally six-rayed, but not infrequently five-rayed. The rays are rather short and plump, covered above with numerous small, short, crowded spines, which are usually unequal in size and mostly capitate, but sometimes most of them are more slender and clavate. The dorsal spines generally form an irregularly reticulate or areolate pattern, but are sometimes acervate, forming nodular groups in one variety. Sometimes they are more unequal in size, the larger ones standing in one or more radial rows, and not acervate. The median rows may be distinct or indistinct. More rarely the spines are all nearly equal and of the smaller sort; sometimes they are subequal, crowded, and all of the larger sort.

Superomarginals similar to the dorsals. Inferomarginal spines a little longer, usually in two or three rows. Peractinals in one or two rows. Adambulacral spines diplacanthid.

Minor pedicellariæ usually numerous. Frequently, but not in all varieties, nor in the young, there are a few very large, stout, stone-hammer-shaped or wedge-shaped serrate dermal pedicellariæ on the sides of the rays or on the interradial spaces beneath.

Its known distribution is from Vancouver Island to Yakutat and Dutch Harbor, and St. Paul's Island, Alaska. It is abundant between tides on rocky shores and in shallow water.

Owing to its great variability, especially in the dorsal spines, it seems to me desirable to distinguish several named varieties, which are described below. The varieties often appear as different as distinct species.

The oral spines in this species are more feebly developed than in most of the allied forms, but vary considerably. The peroral spines usually consist of only two rather short apical ones on each jaw, usually distinctly stouter than the adorals, usually straight, but sometimes curved a little toward each other, so that their tips are convergent. The small side-spines are generally lacking and replaced by a pedicellaria, but in some of the larger specimens it is present on some of the jaws and not on others; when present it is small and short, acute, not more than one-third or one-fourth the length of the apical pair, but it is variable.

The epioral spines are rather longer and more slender than the perorals, and like the adorals in form, though a trifle longer. It often happens that one of a pair is lacking on some of the jaws and then the single spine stands nearly in the middle of the jaw. The adoral carina consists of three contingent pairs of adoral plates, besides the epioral; their single spines are decidedly more slender than those more distal, and are a little longer. Double rows of spines usually commence on the fifth to the eighth plate.

The normal young of this species, when 10 mm. to 15 mm. in diameter, have a rather openly reticulated dorsal skeleton, composed mostly of deeply lobed ossicles, with three or four unequal lobes. When 20 mm. to 25 mm. in diameter, they usually have the characteristic spinulation of the adults, though the spines are smaller and much less numerous, and the median radial row is very distinct and pretty regular. The papulæ are few and mostly stand singly. The madreporic plate is small, with but few gyri. The superomarginal and inferomarginal plates are well defined and each bears a single

spine at first. There are no actinal spines in the smaller of these (18 mm. to 20 mm. in diameter), but one row appears in those about 23 mm. to 25 mm. in diameter, and in these the upper marginal plates usually begin to have two or three spines.

This species has been very much confused and misunderstood by writers, owing to the brief and poor description given by Brandt. He described many of his North Pacific invertebrates merely from colored drawings made by or for Mertens, and probably he had no specimens in most of such cases. The starfishes were apparently among those thus described from drawings only, for several were named from their colors and in some cases very little else was given. In some cases Brandt stated that the specimens were lost. His *A. ochracea* and *A. epichlora* were from Sitka, and we may naturally conclude that they would be species commonly found there.

About *A. ochracea* there can be no doubt, for it is very common on the rocks at Sitka and its color is usually characteristic, as well as the coarse spinulation. But Dr. Coe informs me that the most abundant species between tides at Sitka, and the adjacent coasts, is the one now under discussion, and he also states that it is usually dull green or olive-green on the dorsal surface when living, which would at once explain the name *epichlora*. Dr. Coe states that it has the same habits and nearly the same dull-green color as *L. littoralis* (St.), which he had seen in abundance at Eastport, Maine, and that this Alaskan species occurs by thousands in the same way at Sitka, on the rocks at low tides. It also carries its eggs and young in clusters over the mouth, like *L. littoralis*. These facts would, of themselves, make it almost certain that Brandt's species was this common green species, especially as no other distinctly green species is known at that locality.

Moreover, Brandt's description fits this species in other respects better than it does any other. The principal point of difference is that he stated that it was five-rayed, while much the larger proportion of our Sitka specimens are six-rayed. But we also have many five-rayed specimens of exactly the same character from Sitka. As there is no evidence that Brandt's description or Mertens's figure were based on more than a single specimen, this difference is of very little importance. Among the young carried by six-rayed mothers, are found more or less five-rayed ones.

Brandt's description was essentially as follows:

"The disk is of moderate size (about one inch in diameter), subdepressed. The five arms are conical, subdepressed, unequal in

length. The dorsal surface is green, covered with whitish spines, of which the summit is capitate, arranged crowdedly in a reticulate manner. Ventral surface pale rose. Diameter of disk, one inch; length of ray, three inches [probably measured from center of disk]."

Many of our specimens agree very well with this in size and proportion. But the young of *troschelii,* when of this size, would have a very small disk and far more slender and longer rays, which no one could call " conical " or " subdepressed." [1]

Several writers have confounded Brandt's species with *troschelii,* especially more recently. M. de Loriol (1897) has given a full description and excellent figures of *troschelii,* under the name of *epichlora.* The only points of agreement are the reticulate arrangement of the dorsal spines and their capitate form. In *troschelii* the rays are not only much longer and well rounded in life, but its color above is decidedly red or brown. Moreover, although it occurs at Sitka, it is far less common.

The species described and figured by De Loriol (op. cit., p. 231, 1897) under the name of *saanichensis,* from Vancouver Island, appears to be the five-rayed variety of Brandt's species, agreeing very closely with his description. It also agrees very closely with some of our Sitka specimens.

Brandt's original Latin description of *A. camtschatica* (Prod., p. 270) was essentially as follows: Diameter of disk about one inch. Rays six, conical acuminate, scarcely subequal in length, one to one and a quarter inches long, much broader toward the base. The whole back dusky or ochraceous and covered with crowded, pedicellate, truncate-capitate, white or fuscus-white spines, arranged in raised reticulations, forming subregular radial series. He stated that the specimen obtained by Mertens had been lost, but had been well drawn by Postelesius, and that there were other specimens in the museum of the Academy. His first description, however, seems to have been based entirely on the drawing. Later (Middendorff's Reise, 1851, II, p. 32) he gave a rather shorter description in German, which does not exactly agree with the former, but supplements it. According to the later description it has two rows of ventral spines and three of adambulacrals (probably due to alternate plates bearing either one or two spines), and six or seven rows of crowded dorsal spines. Greatest diameter of the largest, three inches; breadth of the disk, one inch; length of arms, one inch and two to four lines.

[1] See description below, page 155.

Both of his descriptions apply very well indeed to many of the ordinary six-rayed specimens of *L. epichlora alaskensis,* so abundant on the coast of Alaska. This agreement is seen not only in the colors, but also in the size and proportions of rays to the disk, the shape and the crowded reticulate arrangement of the spines, etc., while they often form more or less evident rows, as in var. *plena.* This arrangement is characteristic of many specimens of *epichlora,* but not often of *acervata* or *borealis.* Moreover, the longer arms and smaller disk of the latter are at variance with the proportions given by Brandt.

Hence, it seems very probable that his species is either the six-rayed form of *epichlora* or else some very similar Siberian species, and therefore quite distinct from *acervata* or *borealis.* It might, possibly, be the same as our *A. multiclava.* The description is insufficient for real identification.

LEPTASTERIAS EPICHLORA ALASKENSIS Verrill, nov.

Plate XVI, figures 5, 6; plate XXVIII, figures 1, 2; plate LXXXV, figures 1-1*d* (details), 2-2*e* (young).

This is the most common and most normal form of the species. It differs from the type of Brandt mainly in being six-rayed. Disk of moderate size, high, swollen, or plump-looking. Rays six, sometimes five, rather short and stout, rounded. The type specimen has the radii 14 mm. and 46 mm.; ratio, about 1 : 1.33.

Actinal spines in two or three rows, terete or subclavate, larger than dorsals. Dorsal and lateral spines short and very numerous; the dorsal spines unequal, smaller and shorter than the laterals, crowdedly arranged in an areolated or reticulated pattern, usually not forming definite median rows except when young; their tips clavate or capitate, spinulose and striated. Large, stout, erect, wedge-shaped dermal major pedicellariæ are sparsely scattered over the back and sides, especially in the lateral grooves; they are often as broad as the adjacent spines and have wide, obtuse, or truncated, serrate jaws. (See pl. LXXXV, figs. 1-1*d*.)

The madreporic plate is usually quite small and inconspicuous, with comparatively few coarse gyri; but in some of the larger specimens, especially five-rayed ones, it is much larger, with numerous fine gyri. It is nearly always closely surrounded by a circular group of small capitate spines.

There is a complete series of peractinal ossicles, each bearing one large spine. Large specimens may have a rudimentary row of small, usually spinulose, subactinals near the base of the rays.

Sitka, Fox Cape, Yakutat, Dutch Harbor, Aleutian Islands and Wrangel (Harriman Expedition). Common at Sitka at low tide. Many of the specimens have large clusters of very young ones beneath them over and around the mouth. (Pl. LXXXV, figs. 2-2*e*.) Queen Charlotte Islands; Vancouver Island; Puget Sound; etc.

Among the young attached under the mouth of the mother, were both six-rayed and five-rayed ones; the former much more numerous.

Among 630 young, taken from several six-rayed mothers, and carefully counted, there were 596 of the six-rayed sort; 31 five-rayed; 3 four-rayed. I have seen no adults that are four-rayed.

A six-rayed specimen from St. Paul's Island (coll. H. W. Elliott, U. S. Nat. Mus., No. 3267) is somewhat peculiar. It is 90 mm. in diameter, with the rays narrower, more depressed and more acute than usual, so that it resembles *A. borealis* in form. But the dorsal spines are much as in *alaskensis,* very numerous, crowded, arranged in a reticulate or areolate manner, and all capitate. The marginal rows are double, and also the interactinal row proximally. These spines are stout, clavate. The adambulacral spines are stouter than usual, especially the outer ones, and decidedly clavate. On the sides of the rays are a few large, erect, blunt pedicellariæ, nearly as stout as the adjacent spines. This, like several other odd specimens, may be a hybrid between *L. epichlora* and *A. borealis.*

LEPTASTERIAS EPICHLORA ALASKENSIS, Var. CARINELLA Verrill, nov.

Plate XVI, figures 1, 2.

Normally six-rayed. Rays short, rounded. Dorsal ossicles and spines small, capitate, arranged as in *alaskensis,* except that there is a distinct median radial row, larger than the rest. Infero-marginal and oral spines as in typical specimens. Large erect major pedicellariæ are present sometimes.

Most of the examples of this variety are young, up to 50 mm. in diameter. Probably there is a general tendency for the median dorsal row of spines to become indistinct in larger specimens, though this is not always the case in this species.

Sitka and Dutch Harbor, Alaska (Prof. W. R. Coe, Harriman Expedition).

LEPTASTERIAS EPICHLORA ALASKENSIS, Var. SIDEREA Verrill, nov.

Plate XVI, figures 3, 4.

Disk large; rays usually six, rather short and stout. Radii, 14 mm. and 45 mm.; ratios, about 1 : 3.2; breadth of rays at base 12 mm.

Dorsal spines very numerous and so crowded in the rows and groups that their capitate tips are nearly in contact. The larger ones are nearly even in size and height over the whole dorsal and lateral surfaces; they are short, stout, strongly capitate, with roundish finely spinulose tips. Along the median lines they form radial ranges or three or four irregular, crowded rows; between these and the usually double marginal rows, they are irregularly reticulated, or stand in little groups and short oblique rows. Small ones of the same form are scattered between the larger ones. Ventral spines are longer, rather stout, clavate, arranged mostly in three rows, two of which are inferomarginals and one peractinal.

Adambulacral spines, slender, slightly clavate or obtuse, either one or two to a plate irregularly. They bear groups of minor pedicellariæ.

Dermal major pedicellariæ very few, mostly marginal and interactinal, small, long-ovate; smaller acute-ovate ones are attached within the ambulacral grooves. None of the large, wedge-shaped, serrate ones were found on any part.

The dorsal skeleton is firm, composed of larger and smaller imbricated ossicles. Papulæ rather numerous and small for a *Leptasterias*.

In form and proportions this is very similar to *alaskensis*, but it is so different in the size and arrangement of its dorsal spines that in the absence of a series of specimens I should have supposed that the differences of spinulation might be specific. The major pedicellariæ are somewhat different in the two. The types of this variety have none of the remarkably large, stout, dentate ones, so characteristic of *alaskensis*. A large series of specimens, however, shows that this is only a peculiarity of certain specimens.

Sitka, Dutch Harbor, and Yakutat, Alaska (Dr. W. R. Coe, Harriman Expedition); Puget Sound.

LEPTASTERIAS EPICHLORA MILIARIS Verrill, subsp. nov.

This is a small variety with pretty numerous, small, crowded, slender spinules, so that it resembles *L. æqualis*. Rays usually six, sometimes five. Radii, 5 mm. and 16 mm.; ratio, about 1 : 3.2. The median radial ossicles bear small, slightly larger, capitate spines surrounded by a group of smaller ones. Other dorsal ossicles usually bear a single small, capitate spine with a cluster of minute ones around it. The superomarginal plates bear one larger spine and a number of unequal smaller ones, several of which stand on the descending apophysis. The inferomarginals usually bear two small

divergent spines. The peroral and adoral spines are all small and slender, as in the young of the more typical forms.

Cape Fox and Sitka (Harriman Expedition); Queen Charlotte Islands (Canadian Geological Survey).

This variety, which is remarkable for its small and uniformly crowded spinules, is liable to be mistaken for *L. æqualis*, which it closely resembles dorsally. It can easily be distinguished by its much feebler oral spines, which in the latter are larger and stronger than usual in this group.

Variety REGULARIS Verrill, nov.

Rays usually six, longer and more slender than usual, regularly rounded and gradually tapered. Radii, 6 mm. and 25 mm. Dorsal spines numerous, but not crowded, nearly all capitate, and less unequal in size than in most varieties. The dorsal radial row is distinct, each ossicle bearing two to four spines; two or three stand together on many other ossicles. Both marginal rows and one interactinal row mostly simple, one spine to a plate. Adambulacral, adoral, and oral spines as in other varieties. The second short interactinal row of ossicles, bearing spines, is not present, as it is usually in other varieties when of the same size, and this is probably the cause of the slenderness of the rays.

Cape Fox, Alaska (Harriman Expedition).

Variety SUBREGULARIS Verrill, nov.

The type is a small six-rayed specimen from Sitka, Alaska (Prof. W. R. Coe, Harriman Expedition). It has the same form as *alaskensis*. Its marginal spines are different. The superomarginal row is regular and nearly simple, only one spine usually standing on a plate; these spines are unusually large for this group, stout, capitate, well spaced. The inferomarginals are similar, but a little longer. There are two interactinal rows.

The dorsal spines are short, thick, mammilliform or capitate; the larger ones form a distinct median row; others, similar, are scattered, and not numerous. The papular areas are large. The adambulacral spines are rather stout, subclavate, irregularly subdiplacanthid.

Variety SUBNODULOSA Verrill, nov.

At first sight this variety might easily be mistaken for the young of *Pisaster ochraceus*, on account of the conspicuous and prominent clusters of capitate spines scattered over the dorsal surface, but they do not form reticulations.

The type is five-rayed and larger than is usual in this species. It equals the large six-rayed specimens of the other varieties. The radii are 10 mm. and 60 mm.; ratio, 1 : 6, for the longer rays. The rays are decidedly unequal, however, in the type, owing to former injury. The arrangement of the dorsal ossicles seems to be much as in the typical form, and *alaskensis,* but the spines are very unequal. The smaller are very numerous, rather minute and capitate, while the larger, clustered ones are larger than usual, with broadly capitate or button-like ends, wider than high. The clusters are most numerous along the middle of the rays, but do not form a regular row; elsewhere they are very irregularly scattered. The superomarginal spines form a pretty regular row of slightly longer blunt spines on some of the rays, but are quite irregular on others.

The single row of inferomarginals and two rows of interactinals are longer, not so stout, bent upward a little, and blunt at the tip. The second row of interactinals may reach nearly to the end of the rays. The adambulacral spines are as in var. *alaskensis.* Papulæ stand between all these rows of spines, either in small groups or singly. Minor pedicellariæ are abundant on the adambulacral spines. Major pedicellariæ are few and rather small, ovate-lanceolate, acute. None of the large, erect, serrate kind were observed.

The madreporic plate is larger than is usual in this species and has thinner and more numerous gyri, probably due to greater age.

When superficially examined this looks like a distinct species. Although the dorsal spinulation appears so different, it is arranged nearly on the same plan as in more typical varieties. The unusual enlargement of the larger spines in the clusters is only an exaggeration of a tendency present in most of the larger typical specimens, which often, also, have the more enlarged and finer madreporic plate. The marginal and actinal plates are nearly as in some more typical specimens. It may possibly be a hybrid between *epichlora* and *troschelii.*

Wrangel, Alaska, July 6, 1899 (Harriman Expedition), type.

LEPTASTERIAS EPICHLORA PLENA Verrill, subsp. nov.

Plate LVIII, figure 1; text-figure 6.

Rays six in the type, rather stout and regularly tapered. Radii are 13 mm. and 43 mm.; ratio, 1 : 3.30.

The dorsal spines are very numerous, areolate, short, subequal, capitate, with rough tops, arranged so as to show five radial bands on irregular multiple rows, separated by large, papular areas, in six

obvious radial rows, three on each side. The median row of spines is distinct, but not prominent. The dorsal ossicles are openly reticulate, several surrounding each papular area, and bearing spines which are so numerous as to be nearly in contact in circles around the areas. They are not very diverse in size. Six to eight often stand in a cluster on the larger ossicles.

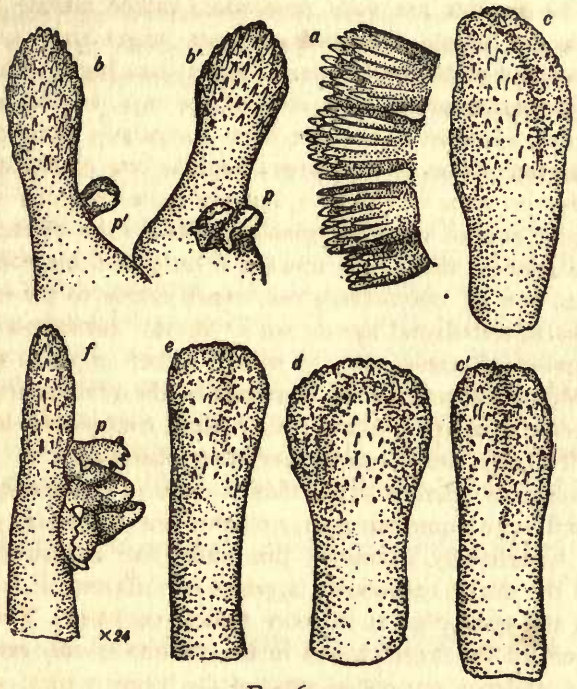

FIG. 6.

Leptasterias epichlora plena, type. *a*, Group of dorsal spines; *b*, *b'*, a pair of superomarginal spines on one plate; *p*, pedicellariæ; *c*, *c'*, inferomarginal spines; *d*, peractinal; *e*, outer, and *f*, inner adambulacral spines with (*p*) minor pedicellariæ. × 24.

The superomarginal spines are similar and stand in groups of two to four on a plate, besides one on the descending apophysis. The two rows of marginal ossicles are separated by a row of large papular areas, bearing small, acute major pedicellariæ.

The inferomarginal spines are longer, stouter, clavate, mostly somewhat flattened, obtuse. They mostly stand obliquely, two to a plate, forming a crowded double row. The peractinal spines are stouter, shorter, more clavate and more flattened, one to a plate, close to the adambulacrals. The latter are much more slender, two to a plate. The outer ones are a little shorter than the inner, stouter, and

mostly a little clavate and flattened. The inner one is slender, tapered, and often bears a small cluster of acute pedicellariæ. Adoral spines are similar but longer. No large dermal major pedicellariæ were found.

Vancouver Island (Canadian Geological Survey).

The type of this is a very distinct form. The equal, crowded, capitate dorsal spines, arranged in areolations and evident longitudinal bands, are notable; the superomarginals, three or four to a plate, are also peculiar. The open reticulation of the ossicles is perhaps more important.

LEPTASTERIAS EPICHLORA PUGETANA Verrill, subsp. nov.

The type specimen from Puget Sound is very peculiar in appearance. The dorsal spines are nearly equal, numerous, crowded, and capitate. They are somewhat areolate, forming circles around the very evident papular areas. The median radial bands are evident, but not prominent. Both the marginal rows are double, with rather stout obtuse spines. The peractinal row has similar short spines, close to the adambulacrals. The skeletal ossicles are stout and rather closely articulated. Large, erect, serrate major pedicellariæ are numerous on the sides of the rays. Radii, 10 mm. and 35 mm.; ratio, 1 : 3.5.

Puget Sound (Professor Ritter, Museum of the University of California).

LEPTASTERIAS (?) DISPAR Verrill, sp. nov.

Plate XVI, figure 7.

Disk moderately large, rays six, angular, depressed, rather short, tapered rapidly. Radii, 8 mm. and 32 mm.; ratio, 1 : 4. Dorsal spines very unequal in size and form. The larger ones are stout and strongly capitate, with large, round, finely spinulose heads; they form conspicuous but irregular median radial rows, two or three often standing on one plate, and also small groups on the disk. Smaller spines of various sizes, partly capitate like the larger ones, and partly slender and tapered or slightly clavate, are scattered over the surface, but mostly in imperfect submedian rows; larger specimens might have them in regular rows.

Marginal spines are similar to the larger dorsals, but not so stout. They form pretty regular rows, one to a plate proximally, but mostly two to a plate distally. Ventral spines are decidedly longer and

more slender, tapered, subacute; they stand in three rows, or sometimes four, at the bases of the rays. Of these the inferomarginals stand mostly two to a plate or three to a plate proximally. Peractinal spines form a simple row, not reaching the tip of the ray. Adambulacral spines small, about half as long as the inferomarginals, very slender, terete, or slightly clavate, mostly two to a plate; sometimes alternately one and two.

Marginal and dorsal dermal major pedicellariæ unusually small, few, compressed, ovate and acute-lanceolate. Many small ones occur along the inner edges of the adambulacral grooves. Minor pedicellariæ are rather few on the dorsal spines, but more numerous on the marginal and peractinal spines; a few are scattered between the spines on the dorsal surface.

The ambulacral grooves are rather shallow and wide, appearing much more open than is usual in other species of this size. The pores are rather large and not much crowded.

The mouth is not sunken. The peroral spines are well developed, but rather short and divergent. The apical pairs are rather longer and stouter than the adambulacral, tapered, subacute; those of the exterior pair are of the same form, from one-half to two-thirds as long, and very divergent. The epioral and adoral pairs are distinctly longer than those further out. Three contingent pairs of plates, besides the epiorals, form the adoral carina. The oral spines often bear small oblong-lanceolate major pedicellariæ.

The dorsal ossicles are unusually large and thick for so small a species. They are wide and deeply lobed and are closely and firmly united together, leaving only very small spaces for the papulæ, which are few and often stand singly. The larger plates form three longitudinal rows besides the superomarginals, which are four-lobed, conspicuous, and elevated in the middle, like the median radials. The latter are strongly imbricated, and have large lateral lobes.

The type is from Dutch Harbor, Unalaska (Harriman Expedition).

This most resembles *L. inequalis,* except in having six rays. The comparatively large and thick dorsal ossicles, angular rays, open grooves, and general appearance of the type indicate that it may be the young of a species that grows to a much larger size, but I know of no species to which it could be referred, unless it be another of the numerous varieties of *acervata* or *epichlora.* But it differs widely from all those forms of the latter, that I have seen, in the large, lobate, dorsal ossicles, arranged pretty clearly in three longitudinal

rows, and without the reticulations, generally characteristic of *epichlora*. The inferomarginal and actinal spines are much longer than in the latter. The ambulacral grooves and pores, the oral spines, and the adambulacral spines are also different, so that the under surface, as well as the dorsal, differs decidedly in appearance from any of the recognized forms of *epichlora*, all of which are much alike beneath, however much the dorsal spines may vary. The pedicellariæ also appear to be peculiar.

It more nearly resembles some of the undoubted young of *A. acervata*, but the lateral and ventral spines are all longer and more slender. It may not be a *Leptasterias*. Genital pores not observed.

LEPTASTERIAS OBTECTA Verrill, sp. nov.

Rays five, rather short and rapidly tapered to slender tips. Radii, 6 mm. and 25 mm.; ratio, 1 : 4.25.

Whole surface closely covered with minute, nearly equal, short, rough-tipped spinules, surrounded with large, dense wreaths of unusually large, blunt-ovate minor pedicellariæ, so abundant as to cover the spaces between the spines and largely conceal the spines, except the tips, thus giving the surface a smoothish appearance like *Henricia*.

The dorsal ossicles are very numerous, small, irregularly reticulated, leaving many small, irregular papular areas; the lateral supramarginal areas are not tansversely elongated, as in *C. cribraria*. The dorsal spinules stand in small irregular clusters of three to six or more; the ossicles are without much tendency to form transverse rows. Carinals not easily distinguished.

Marginal plates small and quite concealed by the abundant pedicellariæ; those in each row usually bear two small spines, sometimes three, a little longer than the dorsals. Proximally there is a short row of intermarginals and of interactinals, each bearing one small spine, partly covered with pedicellariæ. Adambulacrals diplacanthid, the spines small, slender, slightly clavate; adorals longer. The minor pedicellariæ have bases about as broad as the spines; the blades are spatulate and rounded at the tips. The dorsal spinules are mostly four to six times as long as broad; tips are microscopically thorny. Genital pores and reproduction unknown.

Off Kings Island, Bering Sea, in seventeen fathoms. (Coll. Mus. Comp. Zoöl., No. 1208; one dry.)

Genus Stenasterias Verrill, nov.

Type, *S. macropora* Verrill.

Rays slender, six in the type. Dorsal plates are wide, lobed, imbricated, stichasterial in arrangement. Median radial row and dorsolateral rows are nearly regular.

Both marginal rows are formed of wide imbricated plates. One row of small peractinal plates, and a short subactinal row. All these plates are closely covered with clusters of minute spinules. Papular areas small; papulæ few, often isolated. Adambulacral and ambulacral plates not strongly compressed. Ambulacral pores unusually large, in four rows; podia large. Adambulacral plates are diplacanthid. Reproduction unknown.

STENASTERIAS MACROPORA Verrill.

Plate L, figure 7; plate LXXIV, figure 4 (type); plate LXXXIV, figures 5-5*i* (details).

Leptasterias macropora VERRILL, Amer. Journ. Sci., XXVIII, p. 65, fig. 10, 1909.

Disk small. Rays six, long, slender, constricted at base, convex, with a median dorsal row of more prominent ossicles. Radii are 3 mm. and 15 mm.; ratio, 1 : 5. Ambulacral feet and pores unusually large; the pores are triangular, overlapping by their acute angles, and separated only by thin plates. Adambulacral plates are strong, unusually thick radially. Adambulacral spines mostly two to a plate, long, slender, tapered, acute or subacute. The grooves are unusually wide and open. A single row of somewhat quadrate, overlapping interactinal plates, which bear one or two small, rather stout, tapered spines; a series of small, oblong connective ossicles between these and the adambulacral plates, on the basal part of the ray, each of which may also bear a spine. A row of larger, rhombic, imbricated marginal plates, in contact with or overlapping the sides of the peractinals, runs along the under side of the rays, but curves upward to the dorsal side at the disk. These lateral plates usually bear two or three small tapered spines, like the actinals; between them and the actinal plates, and between the latter and the adambulacrals, there are only very small spaces, usually occupied by a single papula.

The dorsal plates are also rather closely imbricated, the spaces between being very few and small, with only one or two papulæ; the median radial plates are thicker and larger, subtriangular, with acute cusps, and concave edges. These overlap, or are imbricated upon, the plates proximal to them, so as to form a median radial ridge or carina. Other dorsal plates are smaller and more irregular. The

dorsal spines are numerous, small, short, stumpy, usually truncate or slightly clavate, but not much enlarged at tip and not much longer than thick. They are in small groups on the larger plates, isolated on the smaller ones. Major pedicellariæ of rather large size, but few in number, are present on the inferior interbrachial areas; these are compressed, acute, lanceolate. Others of similar form, but smaller, are found within the edges of the ambulacral grooves and on the adjacent spines. Minor pedicellariæ are few and minute.

The specimens of this species are small and poorly preserved, having lost many of their spines. It appears to be allied to *L. æqualis* more nearly than to other species, but it is much more slender than that and has much larger ambulacral pores, while the dorsal plates are closely imbricated.

Sitka (Harriman Expedition); Queen Charlotte Islands (G. M. Dawson).

Genus **Stephanasterias** Verrill.

Type, *S. albula* Verrill (Stimpson sp.).

Stichaster (*pars*) VERRILL, op. cit., 1866, p. 551; Perrier, op. cit., 1875, p. 347; Sladen, op. cit., 1889, p. 432.

Stephanasterias VERRILL, Bull. Essex Inst., 1, p. 5, 1871; op. cit., 1874, p. 353; Revision Genera, op. cit., 1899, p. 222.

Nanaster PERRIER, op. cit., 1894, pp. 129, 131, 133.

Dorsal ossicles small, not closely joined, the radial series not in very regular rows; median row more or less imbricated; often not much differentiated, three-lobed; transverse ossicles strong, notably regularly arranged in oblique rows; all covered with numerous crowded, small, subequal spinules, in divergent clusters, arranged in transverse rows on the rays. Papular areas serial, small, with few or solitary papulæ.

Superomarginal plates similar to dorsals; not very distinct, and with similar numerous spinules. Inferomarginal plates oblique and prominent, in a close row, multispinose, their spines longer than those of dorsals. No interactinal plates. Adambulacral spines usually diplacanthid or irregularly triplacanthid. Sucker-feet quadriserial. Pedicellariæ of two kinds, as in *Asterias;* many dermal minor pedicellariæ.

Besides the type, which is autotomous, this genus appears to include *S. gracilis* of the West Indies, which is six-rayed.

These two species have usually been referred to Stichasterinæ by recent writers, but to me they seem closely allied to *Leptasterias.* (See also pp. 40-41, above.) Seen from the inner surface, the dorsal

ossicles are reticulated rather than in longitudinal rows, and the transverse ossicles are larger than the radial; the median row is only a little larger than the others. The papular areas are wider than the plates. Reproduction unknown.

STEPHANASTERIAS ALBULA (Stimpson) Verrill.

Asteracanthion albulus STIMPSON, Invert. Grand Manan, p. 14, pl. 1, fig. 5, 1853.

Stichaster albulus VERRILL, Proc. Boston Soc. Nat. Hist., vol. x, p. 351, 1866; op. cit., 1895, p. 206. Perrier, Arch. Zool. Expér., vol. IV, p. 347, 1875. Duncan and Sladen, op. cit., p. 29, pl. 2, figs. 13-17, 1881. Danielssen and Koren, op. cit., p. 31, pl. 8, figs. 13-15, 1884. Sladen, Voy. Challenger, vol. XXX, p. 432, 1889.

Asteracanthion problema STEENSTRUP, Vidensk. Medd. nat. Foren., p. 240, 1854. Lütken, Grönl. Echinod., p. 30, 1857.

Stephanasterias albula VERRILL, Bulletin Essex Inst., vol. 1. p. 5, 1871; Expl. Casco Bay, p. 353, 1874; Check List, 1879; Expl. by the Albatross in 1883, p. 540, 1885; Revision Genera and Species Starfish, Trans. Conn. Acad., vol. x, p. 222, 1899.

Variety *nitida* VERRILL, op. cit., 1866, p. 351.

A small autotomous, finely spinulated species, with five to nine or more usually unequal rays, normally with six when full grown (var. *nitida*).

In the small specimens, while dividing, there are usually two or three longer, and two to four shorter rays. Mature specimens may have the larger radius 50 mm.; lesser, 6 mm.

The dorsal plates in the larger specimens bear about eight to twelve small, crowded, divergent, costellate and rough-tipped spinules; the median series may be a little larger and distinct. About five close-set, alternating dorso-lateral rows of clusters of spinules proximally; inferomarginal plates bear three to five distinctly larger and longer spines.

Adambulacral plates bear two or three (sometimes four in large specimens), very slender, obtuse spines.

Major pedicellariæ small, lanceolate or ovate; they occur in a row on the inner edge of the ambulacral furrow; on the interradial areas; and sometimes on the adambulacral spines; a few dorsal ones are much larger, stout-ovate, twice as thick as the spinules. Minor pedicellariæ small, with abruptly spatulate valves, nearly as thick as the spinules, numerous between the spines, above and below. Papulæ rather large, mostly in pairs or single.

This is a circumpolar species. Its range extends to Greenland, Iceland and other parts of the Arctic Ocean, and the northern coasts of Europe and Asia.

On the east American coast, it is common from low-water mark to 100 fathoms in the Bay of Fundy and off the coast of Nova Scotia. Dredged at more than 100 stations between N. lat. 46° 50′ and 35° 12′ 30″. Off Cape Hatteras and off S. Carolina it is common in 16 to 50 fathoms. Common south of Martha's Vineyard in 50 to 150 fathoms.

In depth, its range is 0 to 229 fathoms; in one case recorded from 435 fathoms, off Delaware, and once from 1253 fathoms.

Prof. W. K. Fisher informs me that he has North Pacific specimens from the following localities: Stephens Passage, Alaska, *Albatross* Station 4253, in 131 to 188 fathoms, rocks and shells; Shelikoff Strait, Station 4292, 94 to 102 fathoms, blue mud and sand. Off Bering Island, Station 4791, in 76 fathoms, rocks.

The specimen examined by me is from the last named locality, sent by Professor Fisher.

A closely related form, *S. gracilis* (Per.), occurs in deep water in the West Indies.

Genus **Ctenasterias** Verrill, nov. (See p. 53.)

Type, *C. spitzbergensis* (Danielssen and Koren, sp.).

CTENASTERIAS CRIBRARIA (Stimpson).

Plate XXV, figures 3, 4 (type); text-figure 7.

Asterias cribraria Stimpson, Proc. Boston Soc. Nat. Hist., VIII, p. 270, 1862. Ludwig, Zool. Jahr., p. 288, 1886; Fauna Arctica, p. 482, 1900. Bell, Asteriæ, 1881, pp. 494, 505.

Asterias spitzbergensis Dan. and Koren, Norwegian N. Atlantic Expedition. Asteroidea, p. 5, pl. 1, figs. 1-11, 1884.

This small, five-rayed species was thus described by Stimpson:

"This species has very much the aspect of a *Cribrella*. Body thick and tumid, with a smoothish appearance resulting from the great number and small size of the spines. Skin rather pliable or coriaceous; ossicles very slender, but very numerous. Rays five, not contracted at base, and rather higher than broad. Disc rather large. Proportion of the diameters 1:4.8. Ambulacral pores not crowded, and forming two zigzag rows rather than four distinct rows. Some small, acutely triangular major pedicellariæ in the furrows. Ambulacral spines cylindrical with bluntly rounded tips, forming (except toward the extremity of the ray) two regular rows, two to each plate, and bearing small clusters of minor pedicellariæ at their outer bases. Ventral and lateral spines in regular rows, but passing imper-

ceptibly into the dorsal spines on the high, rounded side of the ray;—four of these rows may be counted, in which the spines are small, slender, shorter, and more pointed than the ambulacral spines, and surrounded at base by thick wreaths of minor pedicellariæ, which wreaths, in alcoholic specimens, touch each other at their bases. The dorsal ossicles, with their interspaces, are mostly transverse in direction on the rays, and anastomose pretty closely, except that there is

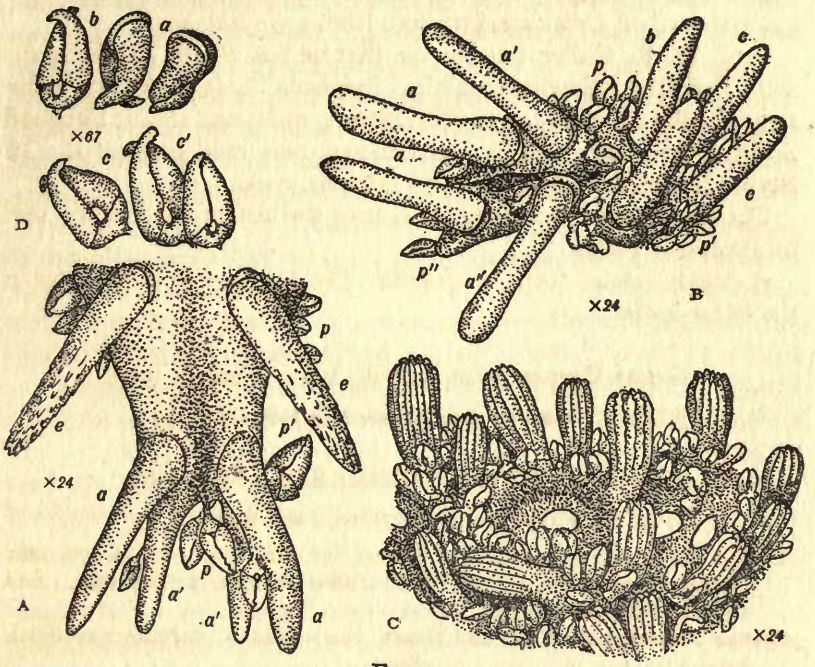

FIG. 7.

Ctenasterias cribraria, No. 6123, U. S. Nat. Mus. (Young). *A*, A jaw; *a*, *a*; *a'*, *a'*, apical spines; *p*, *p*, pedicellariæ; *e*, *e*, epiorals. *B*, Ventral spines; *a*, *a*, inner, and *a'* *a'*, outer adambulacrals; *b*, peractinals; *c*, *c*, inferomarginals; *p*, *p'*, minor pedicellariæ; *p''*, adambulacral pedicellariæ; × 24. *C*, A group of dorsal spines, minor pedicellariæ, and papular pores. × 24. *D*, Pedicellariæ; *a*, two of the minor sort; *b*, *c*, *c'*, small major pedicellariæ. × 67.

on each side a series of transverse membranous interspaces much larger than the rest (often one-fifth the width of the ray) and each containing from two to five papulæ. The papulæ elsewhere stand singly, sometimes two together. The dorsal spines are very numerous, minute, no thicker, and much shorter than the latero-ventrals, and are more or less capitate;—they are somewhat variable in size, and are arranged in groups on the ossicles. Among them are considerable numbers of minor pedicellariæ, which are often half as

large as the spines themselves. On the disc the spines are very much crowded, as they also are along the middle of the ray, forming a more or less distinct median series. The spines of the eyelids and extremities of the rays are much stouter than any of the others either above or below. The madreporic plate is large, but not surrounded by any special arrangement of protecting spines. The minor pedicellariæ in this species are strongly truncated at the extremity. The major pedicellariæ are few in number, and situated on the disc below,—small ones at the inner bases of the labial spines,—and two or three very large ones in the angle of the rays; the latter having stout, almost cylindrical valves, one of which is sometimes notched at the extremity for the reception of the point of the other. A large specimen, probably of this species, was found, in which some of these large major pedicellariæ also occurred on the sides of the rays. Diameter, usually two and one-half inches.

"This fine species appears to be allied to *A. Mülleri*, although so different in aspect.

"Dredged in considerable numbers on a muddy bottom in from twenty to thirty fathoms, in the Arctic Ocean, north of Bering's Straits. U. S. North Pacific Expedition. Capt. John Rodgers."

St. Matthew's Island; Lawrence Bay, in 15 to 20 fathoms (Ludwig).

Natural-size photographs, furnished by Dr. Rathbun, are here reproduced. They are from Stimpson's type, in the U. S. National Museum.

Ludwig (op. cit.), 1886, gives the following information:

"The present examples of this species, known hitherto only northerly from Bering Strait, from a depth of 20 to 30 fathoms, were discovered southerly from Bering Strait. The largest specimen (6.5 cm. across) comes from St. Matthew's Island; the remaining seven specimens are from Lorenz Bay. Among the latter is found one 5 cm. across, which possesses only four arms, while all the others are five-armed. With the exception of the four-armed individual, the specimens from Lorenz Bay are young animals, which have a size of from 2 cm. to 3.3 cm. In five cases the depth and condition of the bottom are given; the former amounts to 15 to 17 fathoms; the latter is designated as 'fine clay mud.'"

This appears to be a strictly arctic and circumpolar species. It has not been taken on the southern coast of Alaska, so far as I know.

The *Asterias spitzbergensis* Dan. and Koren must be very closely related to this, and probably identical. It has the same general

appearance, due to the large number of small, even spinules, and their peculiar transverse arrangement on the sides of the rays; the same reticulate arrangement of slender dorsal ossicles; and essentially the same arrangement of the marginal ossicles and spines. Superomarginal ossicles seem to be equally obscured in both. Both also have three corresponding forms of pedicellariæ. In both, the forcipulate ones are unusually stout and blunt; in both there are adambulacral forficulate pedicellariæ with acute tips, and also a much larger dermal kind, "nearly cylindrical," with wide obtuse valves. The last-named form is very unusual and is a strong indication of specific identity. The principal difference seems to be that in *C. cribraria* the adambulacral plates are described as having two spines, while in *C. spitzbergensis* they bear alternately two and three spines. The differences may well be due to the much larger size of the latter, which was about twice as large as the former.

After carefully comparing specimens of both, my conclusion is that they are identical but variable.

Several young specimens of *cribraria* of different sizes were sent to me by the United States National Museum (No. 6123). These were taken in the Arctic Ocean, north of Alaska, near Icy Cape, in 10 to 15 fathoms, mud and sand. Smith, 1874; coll. W. H. Dall, No. 1212. One of these furnished the details shown in text-figure, No. 7. The larger of these (greater radius, 30 mm.) agrees almost exactly with a specimen of similar size from Spitzbergen, 17 to 23 fathoms, July 25, 1899, sent by the Museum of Comparative Zoölogy. Another, from Greenland, sent with last, is smaller and agrees well with the smaller Alaskan specimens. These were labelled as *A. grœnlandica*, but do not agree with typical specimens of the latter sent to me by Dr. Chr. Lutken.

Genus **Evasterias** Verrill, nov.

A group of long-rayed, diplacanthid starfishes with a rather small disk and a reticulated dorsal skeleton, bearing numerous small spines arranged in a reticulated or subreticulated pattern, or in transverse combs, and having several rows of imbricated interactinal ossicles, of which, in the adult, there may be three to five or more rows. Type, *E. troschelii* (Stimpson). (See also p. 51.)

EVASTERIAS TROSCHELII (Stimpson).

Plate XXII, figures 1, 2; plate XXV, figures 1, 2 (type); plate XXVI, figures 1, 2 (typical); plate LXII, figure 1 (variety); plate CVI, figures 1, 2 (young).

Asterias troschelii STIMPSON, Proc. Boston Soc. Nat. Hist., VIII, p. 267, 1862. Verrill, Trans. Conn. Acad., II, part 2, p. 326 (no descr.) 1868. Perrier,

op. cit., 1875, p. 335 (no descr.). Bell, 1881, pp. 495, 505. Whiteaves, Trans. Royal Soc. Canada, IV, p. 116, 1887.

Asterias brachiata Perrier, Arch. Zool. Expér., IV, pp. 329, 357, 1875 (locality, Gulf of Georgia) (*non* L.).

Asterias (*Diplasterias*) *epichlora* DE LORIOL, Mém. Soc. Phys. et Hist. Nat., Genève, XXXII, p. 19, pl. III, figs. 2-2*d*, 1877 (*non* Brandt).

Several specimens which evidently belong to this species, were collected by the Harriman Expedition.

When well grown it is a large, five-rayed starfish with a small disk and long, round, tapering rays, with a rough uneven dorsal surface, covered with short, unequal, obtusely rounded or capitate spines, which are arranged in an irregularly reticulated or areolated pattern, and always in short rows and more or less clustered or acervate. The inferomarginal and actinal plates bear usually four to six or more rather regular rows of longer and larger, mostly blunt spines. Two irregular series of slender adambulacral spines.

Dr. Rathbun has forwarded two photographs (here reproduced, pl. XXV) of a part of one ray of the type, which seems to be all that is preserved in the U. S. National Museum. Very little can be added to the original description from this fragment. This specimen was less than half the full size. The original description was as follows:

"Rays five, slender and somewhat pentagonal, regularly tapering to a point; disc small. Proportion of the diameters, 1:7. Ambulacral pores in four regular rows. Ambulacral spines in two or three rows, generally two, but occasionally one, to each plate; they are sub-cylindrical, and bear clusters of minor pedicellariæ at the middle of their outer sides. There are four rows of ventral spines (rarely five, near the base of the ray), which are longer than the ambulacrals, slender, with acute tips pointing outward. At the bases of the ventral spines there are numerous minor pedicellariæ, clustered at the outer side in the inner rows, but forming wreaths around those of the outer row. The marginal row of dorsal spines, on the side of the ray, consists of about fifty spines as slender as the ventrals, but capitate, with truncated tips. The other dorsal spines, above, are of two kinds, a larger and a smaller. The larger ones are few in number, shorter but much thicker than the ventrals, capitate, with flattened heads, and are arranged in a pretty regular though somewhat zigzag median row of about twenty-five spines, crowded near the disc, but farther apart near the extremity of the ray. Between this row and the marginal row there are scattered a few more of the larger kind, sometimes in clusters or short rows of three or four. On the disc they form a more or less distinct pentagon, within which

there is another circle, and a spine of large size in the center. The spines of the smaller kind, minute, slender, and truncated, are scattered between the large ones. Minor pedicellariæ are scattered in considerable numbers between the spines, and form wreaths around the bases of the larger ones. The major pedicellariæ are very few in number, small in size, and of rather slender form. Papulæ numerous, but not forming regular groups. Diameter, five inches. (Stimpson.)

"A pretty and well-characterized species, related to *A. epichlora*.

"Habitat, Puget Sound. North West Boundary Commission. Dr. C. B. Kennerly." (Stimpson.)

Two nearly typical specimens were taken by the Harriman Expedition at Yakutat. The larger of these is a dry specimen (*a*) (pl. XXVI, figs. 1, 2). It has the radii 18 mm. and 120 mm.; ratio, about 1 : 6.6; breadth of ray at base, 21 mm. The other (*b*) has the radii 19 mm. and 115 mm.; ratio, about 1 : 6.

In both these specimens the back is deeply areolated and reticulated, the spines mostly standing in single rows around the papular areas, but forming clusters at the principal intersections of the rows. Both have the median dorsal band of spines distinct on the proximal half of the ray, but quite indistinct distally, where the areolations become closer and the spines much more crowded and clustered. The spines in both are short and capitate, unequal in size, the larger ones surrounded by a cluster of smaller ones, but in one specimen (*a*) the larger spines are considerably larger than in the other, with subtruncate rough tips.

In one specimen (*b*) the center of the disk is occupied by a pretty regular figure, formed by five polygonal areas, bordered by spines, and surrounded by ten other polygonal and triangular areas, with others at the radial angles, thus forming a somewhat stellate figure. But in the other specimen (*a*) this arrangement is obscured by the crowding of the spines.

The superomarginal spines form a well defined band, each plate bearing one larger capitate spine, like the dorsals, and two to five or more smaller spines of the same kind. There is a well defined lateral channel which, in one of these specimens (*b*) bears one or two rows of small spines distally, besides some large pedicellariæ, but in the other (*a*) these interpolated spines are almost all lacking.

The inferomarginal row of spines is well defined and nearly regular. In one case (*a*) each plate generally bears only one spine proximally, but on the distal third of the ray there are mostly two equal spines, close together. In the other example (*b*) nearly all these plates bear two stouter and blunter spines, to the base of the rays.

On the proximal part of the rays of the latter there are three rows of strong actinal plates, with a fourth rudimentary row close to the base. The two outer rows usually bear two spines to a plate; the two inner ones only one spine, so that there may be five or six spines in each transverse series. But in the other specimen (*a*) the larger proportion, both of the inferomarginal and actinal plates, bear only one spine, so that the total number is much less; and they are also less stout, a little tapered, and not so obtusely rounded at the tips, so that they appear much more openly arranged and more regular. But in both, these ventral spines are rather large, elongated, subequal, sulcate at the obtuse tips, often bent upward, and frequently compressed when crowded.

Each jaw bears a pair of strong, tapered, blunt teeth, stouter than the adambulacrals, and an external strongly divergent pair, about half as long; on the external end of the jaw-plates there is a close pair of longer and more tapered spines. The next four or five adambulacral plates (adorals) are closely crowded together, and each usually bears a similar long, slender adoral spine. In many specimens eight to ten adoral plates are monacanthid, but in the largest example they become diplacanthid at about the fourth to the sixth, varying on the different rays.

The more distal adambulacral plates are pretty regularly diplacanthid. The two spines are nearly equal, and on the middle of the rays are about equal in length to the actinals; but toward the mouth they gradually become much longer, more slender, and acute; most of them are tapered but not acute. They bear, above mid-height, large clusters of forcipulate minor pedicellariæ, with which some small forficulate pedicellariæ, of about the same size, are often intermingled.

Thick wreaths of clusters of minor pedicellariæ also occur on all the ventral and upper marginal spines, but only in small numbers on the dorsals. They also occur as dermal pedicellariæ, scattered over the dorsal surface.

Major pedicellariæ are few on some specimens, but abundant on others, especially on the lateral channels and on the adoral spines. The largest are on the interradial areas. These are mostly ovate-lanceolate, or regularly lanceolate, compressed, and have very acute tips. Papulæ are very numerous.

Color, in life, is often bright rosy red or purplish.

A small dried specimen (*a*) from Wrangel, Alaska, has all the essential characters of the larger ones. Its radii are 8 mm. and 48 mm. to 55 mm.; ratios, 1 : 6 or 1 : 7, according to the rays measured.

The rays are slender, well rounded above, and regularly tapered. The dorsal surface is covered with very numerous small spines arranged in an irregularly reticulated pattern, much as in the adult, but on a much smaller scale. The spines are capitate and unequal.

The upper and lower marginal spines and two rows of actinals stand in simple regular rows, one to a plate. The peractinal row extends to the tips of the arms, the spines becoming very small distally; the first row of subactinals only extends to about the middle of the rays; a few spines occur on a rudimentary synactinal series at the base of the arms.

The adambulacral plates usually bear alternately one and two slender spines. The minor pedicellariæ occur in clusters on nearly all the spines; major pedicellariæ are very few and small.

Specimens considerably smaller than this are similar in character and could hardly be mistaken for any other species.

Two small specimens (*d, e*) were taken by Dr. Coe at Sitka and preserved in alcohol. The larger (*d*) (pl. XXII, figs. 1, 2) has the radii 12 mm. and 55 mm. The dorsal spines show above the general surface only slightly, their rounded tips alone being visible, but their clustered arrangement is apparent, and gives the surface an irregular, roughly uneven appearance. The wreaths of minor pedicellariæ are dense and attached near the tips of the spines, and with the abundant papulæ they closely cover all the spaces between the spines.

The marginal and ventral spines are more conspicuous, their large clusters of pedicellariæ being attached lower down. These spines form four very regular longitudinal rows, the upper marginals being smaller than the others. The adambulacral spines are almost concealed by their large clusters of pedicellariæ.

The smaller example (*e*) has the radii 5 mm. and 40 mm. The rays are round and slender, rather rigid, and taper gradually. The surface and spines agree with the preceding, except that the dorsal spines are even less apparent and the surface less uneven, though the clustered arrangement of the spines is still evident.

The color of these alcoholic specimens is light rusty-brown. In life it is usually light red.

VARIATIONS.

A larger specimen (*f*) from Puget Sound (Kincaid) has the radii 22 mm. and 162 mm.; ratio, about 1 : 7.3. The five rays are long, well rounded and gradually tapered. It agrees pretty well with those described above, but the reticulations made by the dorsal spines

are less complete and less regular, both on the rays and on the disk. Radial bands of spines are not distinct. The spines are also smaller and less decidedly capitate.

The inferomarginal and actinal spines mostly stand singly, so that there are usually only four or five rows near the base of the rays, but on some of the rays more or less of the plates bear two spines.

The adambulacral spines are long and slender, about equal in length to the actinals on the greater part of the length of the rays; but toward the mouth they increase in length more rapidly than the actinals, becoming decidedly long and slender on the adoral plates.

Major pedicellariæ are abundant in the lateral furrows, interradial areas, between the actinal spines, in clusters on the adambulacral spines, and also on the inner edges of the ambulacral plates. They are of moderate size, compressed, mostly acute-ovate or ovate-lanceolate in form. Those on the sides and bases of the rays are the larger. The clusters on the adambulacral spines are in many cases composed of small-sized forficulate major pedicellariæ, but on other spines they are mixed with forcipulate minor pedicellariæ in varying proportions.

Minor pedicellariæ occur in small numbers on nearly all the spines. They are also abundant between the dorsal spines, on the papular areas, and on the surfaces of the lateral channels. They generally stand singly when dermal. The papulæ are small and very numerous, in large clusters.

In the Museum of Comparative Zoölogy I have studied a good series, including some that are quite small.

One series from Mendocino, California, includes specimens only 35 mm. to 40 mm. in diameter (No. 1191). Lot No. 1192, also from California, includes three young. No. 1195 is from Alaska. Nos. 1191, 1194, 1187 are typical specimens from the Gulf of Georgia (coll. A. Agassiz). Of these, No. 1191, was labelled as *Asterias brachiata* of Perrier. It is probably a cotype of his species, but is not the one of which he gave measurements. He gave no locality for his species. There can be no doubt that the type was from this lot and that it is a synonym of *E. troschelii* (Stimpson). No. 1190 is a short-rayed, close-spined variety from Mendocino, California.

No. 1906, from Friday Harbor, Puget Sound (Professor Kincaid), is a short-rayed specimen with coarse spinulation (radii, 22 mm. and 140 mm.).

The dorsal spines are decidedly longer than usual, capitate, conspicuously reticulated and areolated, with no distinct median radial

rows. Thus its dorsal spinulation is similar in appearance to that of some examples of *Pisaster ochraceus*. But the stout marginal spines and three regular rows of actinals are arranged nearly as in the typical *troschelii*, and its adambulacrals are irregularly diplacanthid. No large, unguiculate dorsal pedicellariæ were found. Although it looks like a hybrid with *ochraceus*, it is near the type of var. *alveolata*.

The dermal major pedicellariæ are small, lanceolate, pointed. Minute minor pedicellariæ are sparsely scattered on the integument of the back, and form thin wreaths around the spines, but on the adambulacral and actinal spines they are abundant, forming distal clusters, in which there are also a few small, scattered, pointed major pedicellariæ.

The papular areas on the dorsal side are large and the papulæ very numerous, in large groups; between the actinal and marginal rows they are large but in small clusters.

Some other specimens of this species have the rays much shorter than usual. This is the case with Nos. 1421 and 1432 (Mus. Comp. Zoöl.) from the Gulf of Georgia. In these the dorsal spines are numerous and crowded, areolated or reticulated. They somewhat resemble var. *alveolata*, but the shortness of the rays may perhaps be due to mutilation and imperfect restoration, for the rays are not precisely equal.

One of the larger specimens (about twenty inches in diameter) studied by me is from Esquimault, B. C. (Prov. Mus. B. C.), sent by Dr. Newcombe.

The radii are 43 mm. and 250 mm.; ratio, 1 : 5.8; breadth of rays near the middle, 68 mm. to 76 mm.

The disk and rays were evidently distended with air before drying, as shown by the wide inflated form, and the widely stretched dorsal papular areas; but near the tips of the rays the normal rounded form is retained, with the close reticulate arrangement of the spines.

The dorsal spines are mostly small and acute, standing on the openly reticulated ossicles in short rows, the transverse rows being most conspicuous, especially on sides of the rays. But there is a slightly distinct medial row of somewhat larger and partly capitate spines on the proximal half of the rays. The disk is coarsely reticulated with slightly larger clavate and capitate spines. The madreporite is large, complicated, but not surrounded by any special spines or grooves.

Notwithstanding its great size, the number of rows of marginal and actinal spines is not greater than in some specimens of var. *sub-*

nodosa, not more than one-fourth its diameter. The upper and lower marginals are wide apart; the upper row is mostly single; the lower, mostly double; the peractinal and the first subactinal row are double; the imperfect synactinal row is single so that there are about eight pretty regular and even ventral rows proximally. All these spines and the adambulacrals are shaped as in the specimens already described.

Rather large, acute-ovate, dermal major pedicellariæ are numerous between the actinal and marginal rows, and large clusters of smaller ones are abundant on the adambulacral spines. Papulæ are exceedingly numerous in large groups on the dorsal and lateral areas.

The *Asterias epichlora* of M. de Loriol (*non* Brandt, op. cit., 1897) is doubtless identical with this species, and is not the true *epichlora* of Brandt, which was evidently the common small greenish Sitka species, and probably identical with *A. saanichensis* De Loriol (op. cit., p. 23, pl. II, figs. 3-3*d*, 4, 5). This has been discussed under *A. epichlora.*

The differences that he found, in comparison with Stimpson's description of *troschelii,* are variable characters in this species, as my descriptions above will show. Some of the specimens studied by me agree well with the one figured by M. de Loriol and came from the same district.

The geographical range of this species is extensive. I have studied specimens from Mendocino, California, and Yakutat, Alaska. It was taken by the Harriman Expedition on the Alaskan coast, at Sitka, Wrangel, Orca, and Yakutat. Mr. J. F. Whiteaves, of the Canadian Geological Survey, sent me specimens from the Straits of Georgia, Malaspina Inlet, Discovery Passage, and Queen Charlotte Islands. Dr. C. F. Newcombe sent many specimens from Victoria and Esquimault Harbor, some of large size. I have also examined specimens from Puget Sound (Kincaid) and several other localities. Departure Bay, British Columbia (H. J. Young, Canadian Geological Survey, 1908), many large and small; Gulf of Georgia (A. Agassiz, Mus. Comp. Zoöl.), a good series.

EVASTERIAS TROSCHELII Var. RUDIS Verrill, nov.

The three large specimens (*h, i, j*) about equal in size and form, from British Columbia, appear to belong to this species, though they have larger and swollen rays, and much coarser dorsal spines. One of these has the radii 36 mm. and 252 mm.; ratio, 1:7. The specimens are flattened in drying, the dorsal skeleton being weak, and this makes the rays appear broader.

The dorsal surface is very openly reticulated, with rather small and narrow ossicles, forming large, irregular, angular papular areas.

The dorsal spines are rough, unequal, and numerous, though less numerous than in the type. They are irregularly and coarsely reticulate in arrangement; and toward the base of the rays, especially on the sides, the smaller ones form short transverse rows or combs on the borders of the larger, transversely elongate, papular areas.

The larger spines, which are relatively few in number, are short, strongly clavate or subtruncate, and striate at the tips, mostly scarcely higher than broad. These larger spines often form an irregular median radial row proximally; others are irregularly placed on the nodes of the larger reticulations. Toward the ends of the rays, they become much more numerous and sometimes stand in small groups.

The smaller spines are very much smaller, mostly tapered and subacute, but some are obtuse and many are spinulose at the tip. The whole dermal surface, including the papular areas, is covered with numerous small minor pedicellariæ. They also form small clusters on the bases of the spines. The superomarginal spines are rather longer than the dorsals and tapered or only slightly clavate, often obliquely truncate; they mostly stand singly on the plates and form a regular row, but on one specimen they stand two or even three on a plate, the secondary ones being smaller.

The inferomarginals are very similar in size and form, but rather more tapered; they usually stand two on a plate, but sometimes singly proximally.

There are usually three rows of actinal ossicles proximally, sometimes four, rarely but two. Many of them bear two or even three spines, others but one, so that the number of rows of actinal spines is variable; but they are always numerous, crowded, nearly equal, and very similar to the inferomarginals, though usually rather longer and more tapered, especially toward the mouth.

The adambulacral spines are terete, much more slender, but about as long as the actinals, they mostly stand alternately, one and two to a plate. Those within the disk, and especially the adorals and epiorals, become decidedly longer (6 mm. to 8 mm.) and more slender. The apical perorals are much shorter and stouter.

The lateral channels, between the upper and lower marginal spines, and also between the latter and the peractinals, are well defined and bear numerous pedicellariæ of both kinds.

The major pedicellariæ are acute-ovate or triangular-ovate, acute at the tip, and not very large. They also occur on the back and

among the ventral and adambulacral spines. The latter bear dense clusters of minor pedicellariæ on the outer surface, and near their tips.

The madreporic plate is large, with numerous fine, forked, radial gyri. It is not surrounded by a special circle of spines.

Another large specimen (*k*) from Victoria, British Columbia, differs considerably in the spinulation, especially on the ventral side.

The radii are 36 mm. and 232 mm.; ratio, 1 : 6.45.

The rays are stout and broad, but unnaturally flattened in drying, so that they taper rather abruptly distally.

The smaller dorsal spines are numerous, mostly in reticulated lines and in short transverse rows or combs, the transverse lines being most conspicuous proximally and toward the sides of the rays, dorsally; not so evident on the disk. These smaller spines mostly stand in a single row on the narrow carina of the ossicles surrounding the large papular areas. Part are slender and acute, about 1 mm. to 1.5 mm. long and 0.25 mm. thick. More than half of them are obtuse or clavate, of about the same length, but from 0.40 mm. to 0.60 mm. thick.

Larger capitate and sulcated spines are scattered among the smaller reticulated spines. They stand on the larger ossicles, and especially along the median radial lines, forming, with many smaller ones, rather irregular radial ranges of spines. On the distal part of the rays the spines become more crowded and the larger ones more numerous, and are then often grouped more or less in clusters.

The madreporic plate is large, with fine radial gyri, and is surrounded by an irregular row of small spines. Minor pedicellariæ are thickly scattered over the papular areas and surround all the spines, in small wreaths.

The superomarginal spines form a pretty regular row, in which the larger, blunt spine on each plate is accompanied by one to three smaller, more acute ones. The ventral spines usually consist of three, often double, rows and a single synactinal row, all crowded pretty closely together, and nearly equal in length, but differing in form.

Most of the inferomarginal ossicles bear two equal spines and sometimes three, so that there may be from four to seven spines in each transverse range. These spines are mostly rather short, stout, partly blunt, partly tapered, often bent, some of those toward the mouth becoming longer, subacute, and often excurved. They are mostly about 1 mm. thick and 2 mm. to 3 mm. high.

The ventral ossicles are stout and tesselated; in size, shape, and number very nearly as in the typical form. The adambulacral spines are longer and more slender than in the type, especially toward the mouth, where they increase more in length, some of the adorals becoming 6 mm. to 7 mm. long. They are mostly alternately one and two to a plate. The apical peroral spines are stout and blunt, rather long. The dermal major pedicellariæ are nearly as in the type, but some are larger and stouter. There are few on the dorsal surface.

This large and peculiar variety might well be thought a distinct species, had there not been specimens more or less intermediate in the collections from Victoria and the Queen Charlotte Islands. It may be that it is the condition commonly assumed when grown to unusual size.

In form, size and general appearance this variety resembles *E. acanthostoma,* but the dorsal spines of the latter are much smaller and more acute, and form conspicuous transverse combs.

Victoria and Esquimault Harbor (Prov. Mus. B. C., collected by Dr. C. F. Newcombe); Queen Charlotte Islands (Canadian Geological Survey).

EVASTERIAS TROSCHELII Var. DENSA Verrill, nov.

One young specimen (*g*) from Victoria, British Columbia, is peculiar in having the dorsal spines all nearly uniform in size and form, all being capitate and arranged in a rather close reticulate pattern, the spines standing in single rows and nearly in contact on the reticulating ossicles. Proximally they often form short transverse rows on the sides of the rays, but distally they are rather uniformly crowded and not acervate, nor is there any distinct median radial row, nor any larger primary spines elsewhere.

The reticulations are much smaller, more transverse, and closer than in the typical form; this, and the absence of pedicellariæ in clusters around the large spines, give it a very different appearance, approaching that of the large specimen of *E. acanthostoma,* in this respect.

There are five regular rows of convex, imbricated, ventral ossicles proximally, many of which bear two spines, which are crowded and much like those of the larger form, but rather more slender and less obtuse.

Radii, 13 mm. and 78 mm.; ratio, 1:6.

Near Victoria, British Columbia (Prov. Mus. B. C.).

EVASTERIAS TROSCHELII Var. ALVEOLATA Verrill, nov.

Plate LXII, figure 1.

A five-rayed, conspicuously reticulated variety, with plump, rounded, tapered, subacute rays of medium length. Radii of the type, 22 mm. and 110 mm.; ratio, 1:5. Madreporite large, round, convex, yellow, surrounded by a circle of fine capitate spines.

The dorsal ossicles are narrow, but high, with subacute summits, on which are rows of small, slender, capitate spines. They surround rather deeply depressed, angular, papular areas, variable in size and form, but often hexagonal or pentagonal; larger and more rectangular ones are on the sides of the rays, between the marginals.

The dorsal spines are somewhat unequal, the larger ones standing at the intersections of the ossicles and on the median line, but forming only a very inconspicuous median band; they are not at all acervate.

The marginal and actinal spines form five nearly simple, regularly spaced rows proximally, all of which are similar in size and form, except the upper marginals, which are shorter, thicker, and more capitate. These mostly stand one to a plate, but sometimes two; or there may be one or two small accessory spines on the plate, or on the connecting transverse ossicles. The spines of the other rows are a little longer, short-clavate or obtuse, and mostly one to a plate.

The peractinal and subactinal rows have one or two to a plate, or alternately one and two in places. The synactinal row extends to about the distal fourth of the ray.

The adambulacral spines stand mostly two to a plate; they are rather stout, cylindrical, or slightly tapered, acute.

Pedicellariæ are few. Very small, ovate dermal major pedicellariæ are scattered on the dorsal side; and larger ones, more acute in form, are found on the interradial and marginal areas.

The color, as dried, is dull purple.

Departure Bay, British Columbia (Canadian Geological Survey, 1908).

This looks like a distinct species, but is probably a short-rayed variety of *E. troschelii.* Its rays are not only shorter and thicker, but the areolations are deeper and more sharply defined, while the marginal and actinal spines are larger and fewer, and the rows are fewer and more widely separated. It may, however, eventually prove to be a distinct species, when a more extensive series can be studied.

EVASTERIAS TROSCHELII Var. SUBNODOSA Verrill, nov.

Several specimens, mostly of rather small size, differ from the ordinary variety so much in appearance that they seem to deserve a varietal name, though intermediate specimens occur. In its extreme form small specimens of this variety closely resemble some five-rayed varieties of *L. epichlora,* especially on the upper side. Others, 70 mm. to 80 mm. in diameter, so closely resemble dorsally the young of *Pisaster ochraceus* as to be readily mistaken for that species; but they can easily be distinguished by the subdiplacanthid adambulacral spines, slender actinal spines, and the small pedicellariæ.

The special features of this variety are the conspicuously clustered or somewhat acervate arrangement of the dorsal spines, some of which are larger and thicker than usual, with strongly capitate and more or less flat-topped tips, while there are minute rows of much smaller clavate and capitate spines scattered between them and partly on the skeletal network; the very smallest are often acute.

All of the spines, above and below, bear large clusters of minor pedicellariæ, and small dermal clusters are abundantly scattered on the back, so that, in alcohol, the dermis and most of the smaller spines are quite concealed by them, and the papulæ.

The two rows of marginal and two to four rows of actinal spines are pretty uniform in diameter and regular, but usually crowded, in arrangement; they are nearly as stout as the larger dorsals and somewhat longer, the inferomarginals and actinals being longer than the superomarginals, and a little curved upward. They are mostly a little clavate and obtuse. In the larger examples the inferomarginal and actinal rows become double, so that there may be six or seven rows. The adambulacral spines are crowded, terete, obtuse, becoming, as usual in all varieties of this species, distinctly longer and more slender toward the mouth; they are loaded with clusters of small pedicellariæ and are irregularly diplacanthid.

One typical specimen from Wrangel, Alaska, has the radii 10 mm. and 60 mm.; ratio, 1:6. Another from Victoria, Vancouver Island (Prov. Mus. B. C.), has the radii 22 mm. and 137 mm.; ratio, 1:6.23.

EVASTERIAS TROSCHELII Var. PARVISPINA Verrill, nov.

Plate CVI, figures 1, 2.

Rays five, in the type; firm, rather short, round and plump, tapering rather rapidly distally. Radii, 6 mm. and 28 mm. The whole upper surface in alcoholic specimens is nearly uniformly concealed

by the pedicellariæ and papulæ, so that the small, uniform spines are scarcely visible, and there is no apparent grouping into clusters, nor any evident rows. The clusters of minor pedicellariæ are dense, though not large, but they are mostly in contact with their neighbors, owing to the numerous spines. They seem to be attached close to the tips of the spines.

The lateral and ventral spines form about four distinct, regular, but crowded, evenly spaced rows, and are rather more distinctly defined than the dorsals; but like the adambulacrals, they are well covered by large clusters of minor pedicellariæ.

Color rusty-brown, as preserved.

When dry, the dorsal surface is covered with very numerous, but not closely crowded, small, unequal spines, arranged in small groups or singly, so as to form irregular circles around the papular areas, thus giving the surface an imperfectly and irregularly areolated appearance. The median radial spines are a little larger, forming an irregular crooked row. The dorsal spines are all short, their height scarcely twice their thickness, in the larger ones, but the smaller ones are much more slender. The larger are capitate, with rough rounded tips; others are clavate. The papular areas are numerous, round, rather small, but unequal in size. The papulæ are unequal, and mostly stand singly or in small groups.

The lateral and ventral spines are all a little capitate, shaped like the larger dorsals, but a little longer and larger. They form five pretty regularly spaced, simple rows (sometimes six) on the proximal three-fourths of a ray, separated by four rows of papulæ. Four of these rows of spines extend nearly or quite to the tips of the rays, where they become much crowded. The upper marginal series is usually double proximally, with two spines on a plate, but single distally. A narrow channel with a regular row of round papular areas separates them from the lower marginals. These form a regular row to the tips; it is double on the basal part, two spines standing close together on most of the plates, but distally it appears double by the crowding of the row next below. The latter is separated on the basal third of the ray by a row of small papulæ; but these are absent distally, so that the spines seem to belong to the lower marginal series, as both rows extend to the tips of the rays, but they are probably true peractinals. These are followed by a row of papulæ, and then by a row of subactinals that extends to about the middle of the ray. All these ventral spines are much alike in size and form, and they are pretty regularly and evenly spaced.

The adambulacral spines are crowded in two or three irregular rows, the plates bearing either one or two in irregular alternation. They are about as long as the peractinal spines and resemble them in form, but are more slender. They are mostly clavate with rounded rough tips. The outer ones are the larger. They bear small clusters of pedicellariæ. Minor pedicellariæ also occur in small, dense clusters on all the ventral and dorsal spines, and singly on the dorsal papular areas; they are very small.

Major pedicellariæ are very few. The largest are relatively large, nearly equal to the adjacent small spines in thickness, stout, triangular-ovate, obtuse; these stand erect in the actinal interradial areas. A few very much smaller ones, similar in shape, occur on the adambulacral spines.

The dermal ossicles are numerous and unusually well developed, so that the dried specimen is firm and rigid.

Sitka (Dr. W. R. Coe, Harriman Expedition).

These specimens superficially somewhat resemble *C. cribraria,* but are very distinct in the form and size of the pedicellariæ, in the much stouter dorsal ossicles, in the arrangement of the dorsal spines, and in the form of the marginal, ventral, and adambulacral spines.

This is quite unlike all the varieties of *L. epichlora* in appearance. It was at first thought to be a new species. It may be distinguished from *epichlora* by the small size of the dorsal spines and their areolate arrangement; they are not crowded as in subsp. *miliaris.* If they were all enlarged the appearance would be much as in subsp. *alaskensis.* The numerous regular, even rows of slender marginal and actinal spines are also characteristic. The dorsal ossicles are numerous and form a strong reticulation. No very large, serrate major pedicellariæ occur on the types.

This is, no doubt, one of the regular young forms of *E. troschelii,* but my specimens are not sufficiently numerous to connect it with either of the special varieties of that species. It is apparently most like the typical form.

EVASTERIAS ACANTHOSTOMA Verrill, sp. nov.

Plate XX, figures 1, 2; plate XXIV, figure 3 (type).

A large species with a rather contracted disk and five long, tapered, flexible arms. Lesser radii of the type, 30 mm.; greater radii, 275 mm. Ratio, as 1:9.

It is remarkable for the length of the oral and adoral spines and the adjacent actinal spines; for the numerous crowded ventral spines,

which form six to eight rows; for the numerous very small dorsal spines, mostly arranged in small transverse rows or combs; and for the deep ambulacral grooves and long ambulacral feet.

The adambulacral spines are crowded in three irregular rows, most of them standing two on a plate, but frequently alternating with one on a plate (subdiplacanthid). Those at and near the mouth are very long and rather slender, terete, slightly fusiform, pointed. The longest are up to 8 mm. or 9 mm. long. They decrease in length distally and become more obtuse; about opposite the border of the disk they are only about half as long (4 mm. to 5 mm.), or about equal in length to the adjacent actinal spines, but are smaller and more tapered. They all bear dense clusters of minor pedicellariæ near the ends.

The interactinal ossicles form about five regular close rows, nearly equal in size and form. The synactinal ones are only a little smaller, and like the others may bear two or three spines. Many of the actinal ossicles bear two spines that stand obliquely on the ossicle; hence there are six to eight rows of crowded, nearly equal spines, which are strong, not very long, mostly somewhat fusiform, and tapered distally, obtuse or subtruncate, often slightly compressed, substriate or nearly smooth, mostly slightly curved outward. They bear small, dense clusters of minor pedicellariæ on the outer side, or sometimes small wreaths. Between all the actinal plates are regular papular areas, with clusters of small papulæ. Toward the base of the arms, and especially on the under side of the disk, these spines become longer and more acute, some of the most proximal becoming twice the length of those farther out. The rows of ossicles diverge somewhat at the base of the rays, and the outer ones curve upward.

Separated from the inferomarginals or outer ventral row by a very distinct papular channel, there is a row of strong superomarginal ossicles, each of which usually bears two or three spines, similar to the actinal spines in length, but smaller and rougher, with sulcated tips. This row of ossicles and spines curves upward to the dorsal surface at the base of the rays, and there meets the corresponding row of the next ray.

The dorsal spines, which are very small, nearly equal, either tapered or clavate, with rough sulcated tips, are very numerous, without any regular arrangement. They do not form any distinct radial rows nor any very evident reticulations. Most of those on the basal part of the rays stand in short transverse or oblique rows or combs, varying from two or three to ten or more, but many stand

singly or in small clusters. On the distal third of the rays they become much more crowded and stand in small groups or singly; on the disk they form irregular short rows or imperfect reticulations. Everywhere on the disk and basal half of rays there are large papular areas, with very large groups of small papulæ. The spines are surrounded and partly concealed by small wreaths of minute minor pedicellariæ, which become more abundant on the distal part of the rays. Many others occur among the papulæ. Major pedicellariæ occur very rarely on the dorsal surface in this specimen, and only of small size. They are much more frequent on the submarginal channels and actinal interbrachial naked areas; these are long-ovoid, not very large, tapered, and sometimes with denticulate tips. Others of small size, acute-ovate in form, occur within the margins of the ambulacral furrows. The madreporic plate is large, very porous, with close, very complex, narrow gyri.

The dorsal ossicles are very numerous, rather slender, and loosely reticulated, so as to leave very large papular areas. The actinal ossicles are much stronger and more closely united; and though narrow they are rather thick. Seen from the inside, the spaces between them are deep, squarish and pretty regular. The ambulacral ossicles are very numerous and much compressed, so that they are thin between the pores; but they are elongated in the direction of the depth.

The type and only large specimen of this species was taken at Popof Island, Alaska, by the Harriman Expedition, July 10, 1899, and was sent to me by Professor Ritter. It was unfortunately dried with the rays badly bent, and some of them were broken in transportation.

This species does not appear to be very closely allied to any other, except *E. troschelii.* The latter has more slender rays, with the dorsal spines distinctly reticulated and strongly capitate, fewer rows of ventral spines, and different pedicellariæ. A large series of specimens might, however, show that it is only an overgrown specimen of that species, or of its variety *rudis.*

In the character of the dorsal spines, it resembles *Pisaster confertus;* but the latter is strictly monacanthid, and has shorter rays, a much broader disk, more regularly reticulated dorsal spines, and different pedicellariæ.

Genus **Orthasterias** Verrill, nov.

Long-rayed diplacanthid starfishes with a small disk. Dorsal skeleton consists of stout, wide, subimbricated, four or five-lobed plates arranged in three, five, or more definite longitudinal radial rows, and sometimes with extra interpolated flat ossicles, the rows connected by transverse ossicles. The principal plates bear, on a central boss, large, isolated spines, standing in three to five or more longitudinal rows. The transverse ossicles are strong, oblong-elliptical.

Usually one row of interactinal or peractinal plates, with or without spines, closely united to the adambulacrals and inferomarginals; sometimes they are rudimentary, and without spines; rarely two rows.

The inferomarginals are strong, four-lobed plates, each bearing usually two large spines. Superomarginals are large, usually monacanthid, four-lobed; the descending lobe is large and usually joined directly to the inferomarginals, by overlapping the upper lobe of the latter. The alternate superomarginal plates are usually without a spine in all of our species except *O. forreri, O. leptolena,* and perhaps *O. kœhleri.*

Seen from the interior, the dorsal skeleton is largely composed of the stout connective ossicles, mostly in transverse positions, and somewhat reticulated.

This genus is represented on the Atlantic coast of the United States by *O. tanneri* Ver. and by *O. subangulosa* Ver. (=*Asterias angulosa* Per., name preoccupied) in the West Indies. *O. eustyla* (Sladen) seems also to belong to the genus.

The lateral and dorsal major pedicellariæ are unusually large, and are usually of two or more forms. The larger are erect, wedge-shaped, stone-hammer-shaped, or ovate, with the tips of the valves wide and usually denticulate. Others are more slender, with the valves spatulate or narrowed in the middle and the tips unguiculate, with interlocking teeth. Others similar, or smaller, with acute tips, often occur on the adambulacral spines and margin. Type, *O. columbiana* V.

ORTHASTERIAS COLUMBIANA Verrill, sp. nov.

Plate XXIV, figures 1, 2, 4; plate XXXV, figure 1; plate LXV, figure 2; plate LXXVIII, figures 1-1*e* (pedicellariæ); plate LXXIX, figures 3-3*c* (spines and pedicellariæ); plate CIX, figures 2-2*b* (structure).

The type of this species is a rather large specimen collected at Yakutat, Alaska, by Prof. W. R. Coe, on the Harriman Expedition.

The radii are 18.5 mm. and 157 mm.; ratio, about 1 : 8.5. The disk is small, the five arms are long, rounded or subangular above, and taper very gradually to rather small tips. The dorsal plates are numerous, forming five rows, with some interpolated ones. They are large, wide, considerably thickened or convex, those in the three primary radial rows having more convex centers and forming a low but distinct carina.

The dorsal spines form about five more or less regular rows above the upper marginals, often with some intermediate ones. The five main rows extend nearly to the tips of the rays, the spines becoming rather crowded distally, while proximally they stand well apart, except in the median row. The dorsal spines are all nearly equal, except distally, rather large, cylindrical, or slightly clavate, with obtuse or rounded sulcate tips, and bearing dense wreaths of minor pedicellariæ above or about the middle.

The larger spines are about 4 mm. high and 1 mm. in diameter. The upper marginal plates are also thick and convex; their spines are like the dorsals, though a little larger, and bear similar groups of pedicellariæ. They form a very regular row, one to each alternate plate. Along the middle of the ray they stand about 3.5 mm. to 4.5 mm. apart, but become crowded to 1 mm. or 2 mm. distally. Between the upper and lower marginals there is a rather wide naked channel, crossed by the thickened descending apophyses of the marginal plates, and bearing on the plates many very large, ovate and spatulate major pedicellariæ. These often alternate with the spines; others are irregularly placed.

The inferomarginal spines form two rows, two divergent spines standing obliquely close together on most of the plates. They are similar to the upper ones in size and shape, though many are a little compressed and more strongly sulcate at the tips. They bear large groups of minor pedicellariæ on their upper sides, about mid-height. The inferomarginal plates are strongly convex, with the outer surface elliptical. Another regular row of similar spines is borne by the peractinal plates, close to the adambulacrals, each corresponding to about five pairs of the latter. They extend regularly nearly to the tips of the rays and have papular pores between them. The peractinal plates are rounded and convex.

The adambulacral spines form two very regular and equal rows. They are slender, scarcely tapered, terete, or slightly compressed distally, with blunt tips. They are shorter and much smaller than the adjacent actinal spines. Those on the adoral plates are distinctly

longer and more slender. Four contingent pairs of plates, besides the two apical ones, form the compressed oral carinæ, each bearing a single spine. The epioral spines are like the others. The perorals consist of an apical pair of shorter and stouter spines and a divergent auxiliary spine, of about half their length, on each side.

Major pedicellariæ of different sizes and forms are scattered over the dorsal surface as well as on the lateral channels and on the margins of the ambulacral grooves; others occur on the actinal areas, on the tips of the jaws, and on the adambulacral spines. The largest occur on the marginal plates. These are compressed, long-ovate, oblong-ovate or oblong-lanceolate in a front view; some are very stout, with somewhat spatulate rounded tips, in a profile view; a few are denticulate, others acute. Those of the ambulacral region are more compressed and usually much smaller, though the larger ones are here as wide as the adambulacral spines; most of these are long-ovate or lanceolate and acute. Those on the back are mostly acute-ovate.

The minor pedicellariæ are rather unusually large and form dense clusters around all the dorsal and upper marginal spines at about mid-height, while smaller groups occur on the actinal and adambulacral spines. Papulæ are small and numerous. The ambulacral grooves are wide; the pores, which form four regular rows, are narrow-elliptical, with flaring lips.

A smaller specimen from Queen Charlotte Islands (Canadian Geological Survey, 1878) has the radii 12 mm. and 72 mm.; ratio, 1:6. The dorsal spines are more numerous and longer than in the type, and stand in about five rows. They are all nearly equal and rather isolated, except those in the median radial row, where they stand in a pretty close line. They all bear a dense wreath of minor pedicellariæ on a sheath, at about mid-height. The dorsal ossicles are strong and closely united, convex, with a mammilliform elevation and a central pit, where the spine was attached.

The upper and lower marginal spines are a little longer, but similar to the dorsals; both are in regular rows, but the lower ones often stand two on a plate proximally. Actinal spines similar, in one row. Adambulacral spines long and slender, but rather shorter than the actinals, except on the adoral and epioral plates, where they become decidedly longer. They stand irregularly, one and two to a plate. Adoral carinæ compressed, formed by two or three contingent plates, besides the epiorals. Peroral spines of moderate length.

A good dry specimen taken at Departure Bay, British Columbia, in 18 fathoms, gravel bottom, September, 1908 (C. H. Young), has been sent to me by the Canadian Geological Survey.

Radii, 28 mm. and 190 mm.; ratio, about 1 : 7. The dorsal skeleton is rather firm, though the plates are small, but the plates and cross-bars are numerous, and papular areas are not very large. The median row of spines is pretty close and regular, composed of a single row of large and long, nearly cylindrical, partly tapered, blunt spines, one to a plate. On each side there are two or three less regular, rather distinct rows of widely spaced long spines, like those of the median row, but not half so numerous.

Below the middle of the side there is a more regular row of similar but more numerous superomarginal spines, curving upward, proximally, to the upper margin of the interradial angles. These, like the dorsal spines, have a close wreath of small minor pedicellariæ, usually near the tips, but at least beyond the middle.

Separated from the upper marginal plates by a wide, naked, papular lane, there is a regular double row of large spines, which are the inferomarginals. These spines are shorter and rather smaller than those above, with blunt, fluted tips. They stand obliquely on the plates, the lower one more distal, and close to a similar spine arising from each of a series of small, roundish, peractinal plates, so that the three rows of spines form a series of obliquely transverse, short, close rows, only slightly separated from the adambulacrals. Each peractinal plate corresponds to four or five adambulacrals.

The adambulacral spines are arranged regularly, two to a plate. They are equal, slender, tapered, subacute, shorter and much smaller than the adjacent ventral spines. Carried on the adambulacral spines and within the borders of the grooves, are numerous rather large, lanceolate, subacute major pedicellariæ, many of them equal in thickness to that of the spines, at mid-height, and from one-fourth to one-third as long. On the sides and back of the rays there are also many scattered major pedicellariæ, mostly of still greater size. Some of these are lanceolate, but most are thick, stout, ovate or oblong-ovate, with the tips of the jaws blunt and strongly denticulate.

The dried specimen has been stained by the preparator to a deep red-brown color, probably imitating its color in life.

The largest specimen that I have seen is about two feet in diameter, as dried, it has the greater radii 340 mm.; lesser, 30 mm.; ratio,

1 : 8. It was taken in 25 fathoms, off Victoria, British Columbia, and was sent to me by Dr. C. F. Newcombe, from the Provincial Museum of British Columbia.

It agrees well with the specimen from Departure Bay, in nearly all characters, except those apparently due to greater age. The five rows of large dorsal spines are pretty regular and are arranged as in the latter, as are the marginal and ventral spines. As in the smaller specimen, there are but three rows of ventral spines, standing in the same way, in short oblique groups of three, but these spines are relatively longer, being nearly as long as the upper marginals. Major pedicellariæ are of different sizes and forms, but mostly large, scattered on the back and sides, as already described. The large denticulate form is most numerous.

Alcoholic specimens of this species were also obtained by the Harriman Expedition (pl. XXIV, figs. 1, 2). These have the rays plump and rounded. The wreaths of minor pedicellariæ on the dorsal and lateral spines are so large that they are nearly or quite in contact, over much of the surface. The ambulacral feet are large and crowded. The spines are arranged nearly as in the dry specimen described above.

This species is evidently closely allied to *O. dawsoni,* which I formerly supposed to be merely the young. But the latter has much fewer dorsal and lateral spines and plates, owing to the relatively larger size of the latter. This is especially noticeable when the distal parts of a ray of each are compared, where of the same size; for the present species has at least twice as many plates and spines in the same space. The forms of the spines and pedicellariæ are somewhat different, though similar. The arrangement of the adambulacral and interactinal spines is nearly the same in both, when of similar size. The larger, lateral, spatulate pedicellariæ are more spatulate or lyrate and longer in *dawsoni,* but I have found, in the latter, none of them serrate or unguiculate, while in this some occur with three or four small interlocking apical teeth.

This species is remarkable for its thick and enlarged dorsal plates, which are united so closely together that the papular areas are mostly small. The small interpolated ossicles are flat and angular. The marginal and interactinal plates are also unusually thick and convex.

Yakutat, Alaska (Prof. W. R. Coe, Harriman Expedition); Queen Charlotte Islands (Canadian Geological Survey, 1878); Departure Bay, British Columbia, 18 fathoms (C. H. Young, Cana-

dian Geological Survey); off Victoria, British Columbia, in 25 fathoms (C. F. Newcombe, Prov. Mus. B. C.), very large.

ORTHASTERIAS BIORDINATA Verrill, sp. nov.

Plate LXIII, figures 1, 2 (general of type); plate LXXXII, figures 2-2*b* (spines and pedicellariæ).

The two type-specimens are very much alike and nearly of the same size. Radii of the one figured, 8 mm. and 88 mm.; ratio, 1:11; radii of the other, 9 mm. and 85 mm.; ratio, 1:9:5.

Rays five, long, slender, very gradually tapered, rather acute, well rounded above, and furnished with three regular rows of well spaced, elongated spines, one to a plate, except near the ends of the rays, where there are five rows, and the spines are closer together. Isolated spines also stand on the transverse ossicles, here and there. The dorsal spines are regularly clavate, evenly fluted distally, with the tips obtusely rounded.

They stand on elevations of stout, lobed plates. The median row is distinct, because the spines are about twice as many, though of about the same size and length. The center of the disk is occupied by a prominent five-lobed plate, bearing a spine, and with five stout ossicles radiating out from its lobes, in line with the median rows of the rays, but connecting with five radial spine-bearing plates of the disk, which form a pentagon.

Alternating with these, and a little farther away, are five larger interradial plates, each bearing a spine of larger size.

The dorsal pore is small and surrounded by minute papillæ. It lies between two lobes of the central plate and in an interradius next to that occupied by the madreporite, which is large, very round, and with fine gyri.

The spines are surrounded by close wreaths of very small minor pedicellariæ which are often subbasal, but frequently at mid-height, or distal, and then are attached to the edges of a sheath.

The superomarginals form a very regular row, one to a plate, of rather longer and more slender fluted spines. The inferomarginal row is double, with two spines to a plate; these spines are distinctly longer, more slender, and less clavate than the dorsals, but fluted in the same way. Alternate superomarginals are spineless.

The peractinals are smaller; on several rays they extend only on the proximal third of the ray; on others to the distal fourth.

The adambulacral spines are slender, regularly diplacanthid, widely divergent, forming two remarkably regular pectinate rows,

the inner one with the spines horizontal and meeting or interlocking over the middle of the groove in most places.

The dorsal dermal major pedicellariæ are large, long, mostly compressed, with spatulate and denticulate valves; those between the marginal spines are larger, with oblong or spatulate valves, obtuse and dentate at the tips (see pl. LXXXII, figs. 2-2*b*). Colors yellowish brown, the disk reddish brown.

The type specimens are from Departure Bay, British Columbia (coll. C. M. Young, Canadian Geological Survey).

This may be merely a variety of the young of *O. columbiana,* coming from the same district, but I have seen no intermediate specimens. The remarkable regularity of the adambulacral spines is a striking feature, as well as the regular spaced rows of dorsal and marginal spines.

ORTHASTERIAS CALIFORNICA Verrill, sp. nov.

Plate LXVIII, figure 2 (actinal side of type); plate LXX, figure 5 (actinal side); plate LXXX, figures 3-3*a* (spines and pedicellariæ); plate LXXXI, figures 2-2*b* (pedicellariæ and spines); text-figure 3.

Rays five, elongated, narrow, well rounded above, constricted at base. Disk small. Radii, 9 mm. and 86 mm.; ratio, 1 : 9.5.

Dorsal and marginal skeletal ossicles strong, arranged in rather irregular longitudinal rows, each of the dorsals and superomarginals bearing a single, rather elongated, stout, cylindric or little tapered, blunt spine. The spines are pretty evenly spaced, nearly equal and surrounded above the base (as dried) by a dense wreath of small, ovate minor pedicellariæ. The abactinal spines form five indistinct rows proximally, but only three on the distal fourth of the rays. They are remarkably uniform in size and length. The median row is scarcely different from the others. Those on the disk are similar and regularly spaced.

The superomarginals form a single, regular row; they are like the dorsals, but rather longer. The inferomarginals are decidedly smaller and somewhat shorter. They stand mostly two to a plate; the upper one of the pair bears a half-wreath of minor pedicellariæ. These spines are mostly flattened at the tips. On the proximal half of the rays there is a simple row of peractinal spines, similar to the adjacent marginals and close to them.

Adambulacral spines are mostly two to a plate, rather long, very slender, flattened, larger toward the mouth. Each jaw has a terminal pair of short, notably stout, blunt, peroral spines, and a much longer pair of tapered epiorals.

Sessile major pedicellariæ are large, erect. The larger nearly equal to the spines in diameter, are sparsely scattered on the dorsal side and more frequently on the intermarginal channels; some equally large are also attached to the inner edges of the ambulacral grooves, and in some of the interradial areas below, but most of the axils bear groups of much smaller ones. The larger pedicellariæ are somewhat elongated wedge-shaped, with broad, spatulate jaws, strongly dentate or unguiculate at the wide tips.

The madreporite is large, flat, fine-grained, flush with the surface, with a few spines and large pedicellariæ around it, but with no special bordering. Ocular or apical plates covered with many small spines.

Off San Francisco, probably in rather shallow water (Prof. W. E. Ritter).

ORTHASTERIAS KŒHLERI (de Loriol).

Plate LXXV, figures 3-3*c* (type, after de Loriol).

Asterias kœhleri DE LORIOL, Mém. Soc. Phys. et d'Hist. Nat. Genève, XXXII, No. 9, p. 21, pl. III (XVIII), figs. 3-5, 1897.

The type had the following characters:

Rays five, long, slender, well rounded dorsally. Radii, 10 mm. and 97 mm.; ratio, 1:9.7. Dorsal spines numerous, long (2 mm. to 2.5 mm.), slender, blunt, striated distally, arranged without order. Ventral spines [marginal and peractinal] form three regular rows; they are rather larger and longer than the dorsals. Adambulacral spines long and slender, mostly two to a plate, divergent.

A few large, dermal, dorsal pedicellariæ, some of them 1 mm. long; they are long-lanceolate, acute, dentate at the tip. Major pedicellariæ of unequal sizes occur on the actinal side and on the edges of the ambulacral grooves.

Saänich Inlet, Vancouver Island (de Loriol).

ORTHASTERIAS DAWSONI Verrill, sp. nov.

Plate XXIII, figures 1, 2 (type); plate LXXV, figures 2-2*b* (spines and pedicellariæ); plate LXXX, figures 2, *a-g* (pedicellariæ); plate LXXXI, figures 3-3*b* (spines and pedicellariæ).

Disk very small; rays five, slender, angular above when dry, gradually tapered. Radii of type, 10 mm. and 80 mm.; ratios, 1:8.

Dorsal spines in three regular radial rows, long, tapered, obtuse, or subacute, standing singly on the plates.

Type examined Dec 2 1921

Superomarginal spines similar to dorsals, in a simple regular row. Each alternate plate usually bears a large spine. On the disk about fifteen similar spines form a circle around the center, a few spines standing within it. The circle is formed by five pairs of interradial spines and five isolated radials.

The stout dorsal ossicles are articulated transversely and longitudinally, so as to leave large, squarish interspaces, carrying numerous small papulæ. Minor pedicellariæ form dense wreaths around all the dorsal and upper marginal spines at about mid-height.

Madreporic plate small, flat, with fine gyri. The upper marginal plates are stout, with a broad, obtuse apophysis extending down to the lower marginals, but leaving triangular papular areas between, so that there is a wide naked lane between the upper and lower marginals. A few very large major pedicellariæ, with wide spatulate blades, occur on this area. The lower marginal plates are also stout and prominent, each one usually bearing two prominent, subacute, divergent spines, which are nearly as long as the upper ones, but much more slender and twice as numerous. Their large clusters of pedicellariæ are mostly confined to their upper side. A less regular row of similar spines is borne on the small peractinal plates, each of which corresponds to about three adambulacrals.

The adambulacral spines form two very regular rows of rather long, slender, slightly tapered spines, which are often flattened at the tips. Those of the inner row are a little shorter than the outer ones, and more acute. About four of the adambulacral plates correspond with one marginal. There is a row of small papular areas between the peractinals. A few small ovate pedicellariæ sometimes occur on the adambulacral spines and in the grooves. The small actinal interradial areas bear groups of small, long-ovate major pedicellariæ of several sizes.

The very large dermal major pedicellariæ on the sides of the rays are not compressed, often nearly as stout as the adjacent spines, and in a profile view the blades are broadly spatulate with abruptly rounded ends, but not unguiculate nor distinctly serrulate, so far as observed.

Ambulacral grooves wide; sucker-feet large, placed in four regular rows.

Queen Charlotte Islands (Dr. G. M. Dawson, Canadian Geological Survey, 1875).

ORTHASTERIAS MERRIAMI Verrill, sp. nov.

Plate XVIII, figures 4, 5 (type); plate XIX, figures 1, 2; plate LXXV, figures 1-1*d* (spines and pedicellariæ, No. 1181). = katherinae

A large six-rayed species, with long, round, gradually tapered rays. Disk of moderate size. In the type-specimen, from off Juneau, Alaska, the radii are 17 mm. and 112 mm.; ratio, about 1 : 6.5.

Dorsal ossicles broad, strong, convex, and firmly united, with small papular spaces intervening; spines well spaced, conspicuous, stout, but not very long, cylindrical or a little tapered, obtuse. They stand singly on the ossicles and are surrounded at base by large wreaths of pedicellariæ. They form an irregular radial row and two or three indistinct or imperfect rows each side of it, with smaller spines interpolated. The upper and lower marginal spines form equal regular rows, one spine on each plate. These spines are larger and longer than the dorsals, mostly conical and subacute; those in the lower series are distinctly longer, especially near the base of the rays. Those in the upper row bear large, dense, complete wreaths of pedicellariæ; those in the lower row have them only on the upper side. The two rows are separated by a naked channel which becomes wide proximally and bears large, ovate major pedicellariæ, clusters of minor pedicellariæ, and a row of papular pores. At the base of the rays are two close rows of interactinal spines, similar to the lower marginals. Of these, the outer row is close to the marginal, but with small intervening papular pores, and it extends nearly to the end of the ray. Its ossicles are rounded, convex, and nearly as large as the marginals. The inner row extends only about half the length of the ray. Many of the actinal spines are flattened or acuminate at the tip; others are obtuse.

The adambulacral spines on the middle and distal plates stand one or two to a plate, alternating irregularly, but on the proximal fourth of the ray they are mostly one to a plate. They are rather stout, shaped like the actinal spines, but smaller and shorter, varying in size, mostly obtuse, but the smaller ones often acute. Toward the mouth they become longer, more slender and subacute. The peroral spines are large and strong and nearly meet over the mouth. The two apical peroral spines, which are much stouter than the adorals, but not so long, are straight, tapered, a little flattened, obtuse; the smaller side-spine is about half as long, but of the same shape. They bear small, ovate, forficulate pedicellariæ. The epiorals and adorals are similar in form, distinctly longer than those farther out,

slender, terete, and evenly tapered. The adoral carina consists of three pairs of closely contingent plates, besides the epiorals. Large, ovate, major pedicellariæ occur between the interactinal spines.

The major pedicellariæ, between and above the marginal spines, are still larger, strongly compressed, ovate, obtuse, not serrate. The minor pedicellariæ not only form large wreaths around the middle of the dorsal and lateral spines, but also occur in clusters on the papular areas.

A smaller specimen (pl. XIX, figs. 1, 2) was taken at nearly the same place as the type, and is now preserved in alcohol. According to Dr. Coe's notes the color of this, in life, was nearly uniform deep yellow, but paler ochre-yellow on the back. Radii, 14 mm. and 66 mm.; ratio, about 1 : 4.7. The larger dorsal spines are in five irregular rows, with some smaller ones interpolated. Only a few of the proximal adambulacral plates are monacanthid.

In alcohol it has a rigid appearance and is firm to the touch, owing to the abundant flat dorsal ossicles. The principal spines are conspicuous above the general surface, blunt and sulcated at the tips, but are surrounded proximally by thick, fleshy sheaths. The wreaths of minor pedicellariæ, which are attached to the sheaths, are regular and dense, and with the papulæ they entirely and closely cover the intervals between the spines. The larger ventral spines are conical, acute, and stand in two very regular rows. A few smaller spines belong to a synactinal series. The ambulacral feet are large and have large suckers.

This species is known only from a few specimens. One was taken off Juneau, in 20 fathoms, June 6; another, in Glacier Bay, 10 fathoms, June 10, by the Harriman Expedition, 1899 (W. R. Coe). Another is from the Gulf of Georgia (No. 1181, Mus. Comp. Zoöl.). The species is dedicated to Dr. C. Hart Merriam.

The only west American species having any marked resemblance to this, when adult, is *O. columbiana.* The latter, however, is a five-rayed species, with the dorsal spines fewer, much longer, and in more definite rows. Its marginal and actinal spines are also longer and more cylindrical, but they are arranged nearly in the same way. Its adambulacral spines are much more slender and form two regular rows. Its major pedicellariæ are larger, stouter, and differently shaped. When very young this species probably resembles *Leptasterias coei,* or some of the allied species with six rays, but would probably have fewer marginal and actinal spines.

Subgenus **Stylasterias** Verrill, nov.

Interactinal plates rudimentary or small, disk-like, standing edgewise, and spineless. See p. 48.

ORTHASTERIAS FORRERI (de Loriol).

Plate LXV, figure 1 (dorsal side); plate LXVI, figures 1, 2 (dorsal and actinal sides); plate LXX, figure 7 (portion enlarged); plate LXXVII, figures 1-1*d* (spines and pedicellariæ); plate LXXX, figures 1-1*e* (pedicellariæ, etc.).

Asterias forreri DE LORIOL, Notes pour servir a l'étude des Echinodermes, No. II, Recueil zoologique Suisse, IV, No. 3, June 23, p. 401, pl. 18, fig. 1, 1888.7 Jennings, Johns Hopkins Univ. Circular, No. 195, p. 16, 1907 (habits, name not used); Univ. Calif. Publ., Zoöl., IV, pp. 53-185, 19 text-figures, 1907 (behavior).

A five-rayed species with long, gradually tapered, convex rays, covered with long, tapered, well spaced spines and with a multitude of remarkably large, unguiculate minor pedicellariæ in large circumspinal wreaths.

The largest specimen (No. 1823) has the radii 20 mm. and 215 mm.; ratio, 1 : 10.75. Another from the same place has them 11 mm. and 116 mm.; ratio, 1 : 10.50. A third specimen (No. 1431) is intermediate in size.

The dorsal spines stand mostly in three pretty regular rows, one to a plate, but usually with an imperfect, more lateral row on each side proximally. They are elongated, up to 6 mm., tapered, terete, obtuse or subacute, nearly smooth, not fluted, surrounded basally by very broad, loose wreaths of notably large, sharply unguiculate minor pedicellariæ. The superomarginal spines are similar, rather longer, one to a plate, in a regular row, rather low down on the side.

The inferomarginals are still larger, up to 8 mm. on the larger specimen, placed two to a plate, pretty near the adambulacrals. They are mostly obtuse, with the tips wider and flattened, or, in the case of the lower one, often gouge-shaped. There are no peractinal spines.

The adambulacral spines are two to a plate, close together, forming two pretty regular close rows. They are slender, unequal; the outer one is longer and larger, usually flattened and wider at the tip, and commonly gouge-shaped.

The orals are shorter, decidedly stouter, flattened, somewhat clavate and blunt.

The dorsal and lateral papular areas are large. In the narrow lane between the inferomarginal and adambulacral spines there is a row of small papular areas; peractinal plates small, flat, standing edgewise, seldom visible without cleaning; easily seen from inside.

The major pedicellariæ are large and of several forms. The larger dorsal ones are large, stout, erect, wedge-shaped, blunt, with several small terminal denticles on each valve. They are often as thick as the adjacent spines. Others are more slender, with spatulate valves, terminating in about three curved, interlocking teeth. The large marginal ones are very large, ovate, wedge-shaped or hammer-head-shaped, with dentate valves. Those on the adambulacral borders and spines are few and smaller. The madreporite is rather large, with very fine gyri, without special bordering spines.

Monterey Bay, California, Nos. 1823*a*, 1823*b* types; No. 1431, Alaska ? (Mus. Comp. Zoöl.).

This species is easily distinguished from all those related to it by the unusually large and peculiar abundant minor pedicellariæ, and from most large species by the small number of rows of dorsal spines. The alternate superomarginal plates are not spineless, as in several allied species.

ORTHASTERIAS FORRERI FORCIPULATA Verrill.

Plate LXII, figures 2, 3 (dorsal and actinal of ray); plate LXX, figure 9; plate LXXXVIII, figures 6, 6*a* (pedicellariæ).

Asterias (*Urasterias*) *forcipulata* VERRILL, Amer. Journ. Sci., XXVIII, p. 67, 1909; Amer. Naturalist, XLVIII, p. 542, 1909.

Rays long and slender, gradually tapered; length of ray, 325 mm.; breadth, not including spines, 28 mm.; disk small. Dorsal skeleton weak, with large papular areas nearly concealed by vast numbers of unusually large minor pedicellariæ.

The dorsal plates are small, three- or five-lobed or stellate, each of the larger ones usually bearing a rather long, tapered, subacute spine; these are well spaced and form about five irregular or indefinite rows. The spines are surrounded by wreaths of the large minor pedicellariæ, but these also occur in larger clusters scattered over the integument between the spines. Large major pedicellariæ are also scattered over the back; these are stout, ovate-lanceolate, with obtuse tips, which are usually strongly denticulate.

On the sides of the ray and separated from those above by a wide papular lane there is a row of small, mostly four-lobed superomarginals, usually bearing a single long spine. They are connected to those above by weak transverse ossicles in series, leaving large papular areas between. The spines are rather longer and larger than those of the dorsal surface. Between these and the adambulacral spines there is a single row of stouter spine-bearing plates, the inferomar-

ginals; each corresponds to five or six adambulacrals. Most of these bear two long, tapered spines, usually blunt and somewhat flattened or sulcate at the tips, rather larger than the upper marginals, usually 7 mm. to 8 mm. long. Between their bases there are often scattered large and strong denticulate major pedicellariæ, similar to those of the back, but mostly stouter and more obtuse; with these are some that are much smaller, lanceolate, and subacute. The large pedicellariæ also occur on the naked lanes below, both on the papular areas and on the adambulacral plates. There are a few small, thin, synactinal ossicles connecting some inferomarginals to the adambulacrals, but not bearing spines. The adambulacral spines form two regular close rows, two on each plate; they are slender, tapered, mostly flattened, subacute, about 5 mm. to 5.5 mm. long. The ambulacral pores are large and form four rows.

The dorsal minor pedicellariæ are remarkable for their great size and abundance; in life they probably nearly conceal the whole upper surface and spines, and are borne on slender pedicels. Their blades are strongly bent and very strongly dentate. They are much like those of *O. forreri.*

Their jaws are slender, strongly arched, open widely and usually have thin, sharp, spatulate tips, that look like sharp hooks, when seen in profile. They are about 1 mm. in height. They are not very unlike those on *U. linckii,* but much larger. Color (when dry), grayish brown above, dull yellow below.

The type was from Departure Bay, British Columbia, 18 fathoms, gravel (C. H. Young, Canadian Geological Survey, September, 1908). The disk was not sent to me. Five loose rays were received.

Although this subspecies is somewhat allied to *U. linckii,* and resembles it in form and the arrangement of the dorsal spines, it differs widely in several characters. *U. linckii* has more numerous and larger sacculated spines. It has large groups and wreaths of minor pedicellariæ of unusually large size, but they are not half so large as in this species and are far less abundant dorsally, the larger wreaths being on the lateral spines. They also differ in form. The large, denticulate major pedicellariæ are also abundant on *U. linckii,* dorsally, laterally, and in the grooves (intra-ambulacral), but they are not half so large in this species. In the former the adambulacral plates and spines are much less numerous and less crowded, so that only about four of the plates correspond to one inferomarginal, while in this species there are six or seven to one inferomarginal. In *U. linckii* each adambulacral, on the proximal half or more of the

ray, usually bears a single acute spine, though on the distal part each bears two divergent spines, of which the inner is much smaller and shorter. But in the present species there are two nearly equal, long, slender adambulacral spines to each plate proximally as well as distally.

Another arctic species (*U. panopla* Stuxberg)[1] from Spitzbergen, etc., has more resemblance, for it has few dorsal spines and abundant dorsal groups of minor pedicellariæ. But these pedicellariæ are not of the same form and are much smaller, as also the major pedicellariæ. Its ventral spines are much more numerous, longer and more slender.

ORTHASTERIAS LEPTOLENA Verrill, sp. nov.

Plate LXIV, figures 1, 1*a*, 2, 2*a* (ventral and dorsal sides of types); plate LXXVII, figures 2, *a-d* (pedicellariæ).

The disk is small; the rays five, long, slender, tapered, well rounded. The radii of the larger (No. 18*a*) are 7 mm. and 76 mm.; ratio, nearly 1 : 11. The smaller has radii of 4 mm. and 44 mm.; ratio, 1 : 11.

The dorsal spines of the rays and disk are rather long and of nearly uniform size and length, numerous but not crowded, mostly one to a plate, and pretty uniformly distributed, nearly in quincunx, or in five indistinct, alternating rows on the rays, the median row not differing from the rest. These spines are tapered, but obtuse and rough or subsulcate at the tips, which are often flattened. Between them there are large, denticulate dermal pedicellariæ, often about half as thick as the spines. Papular areas are large; the papulæ small and numerous.

The superomarginal spines form a single regular row, one to all plates. They are similar to the dorsals in size and form. The inferomarginals form a very distinct double row, two to a plate, separated from the upper ones by a rather deep naked channel, with large papular pores. The inferomarginal spines are like the upper ones in form, but a little longer and less tapered, obtuse. There are no spiniferous interactinal plates. The peractinal row is represented by a proximal row of small, narrow, spineless plates, five to ten in number, on the different rays, and joined closely to the adambulacrals. In the smaller specimen these actinal ossicles are rudimentary or lacking.

[1] See Döderlein, 1900, p. 204, pl. IV, fig. 2; pl. V, figs. 1, 2.

Adambulacral spines are irregularly diplacanthid, small, slender, terete or obtuse, about half as long as the inferomarginals and scarcely one-third as thick. The outer ones are a little longer and often slightly clavate; the proximal ones become distinctly longer and more tapered. There is an unusually wide naked space between the adambulacral and the inferomarginal spines.

Oral and epioral spines longer and distinctly stouter.

Remarkably large dermal major pedicellariæ are sparingly scattered over the back and sides. They are mostly of two forms; the larger are stout, erect, compressed, ovate, with a stout base, often nearly as thick as the adjacent spines; apex a little acuminate, obtuse. The others are about as long, but not so stout, compressed, contracted in the middle, with the blades a little spatulate and dentate or unguiculate at the tips. Much smaller, simple, lanceolate ones also occur. Thick wreaths of rather large minor pedicellariæ surround the basal half of the dorsal and superomarginal spines; on the inferomarginal spines they form secund groups.

The madreporite is rather prominent, with very fine gyri; it is not surrounded by special spines.

The color, as dried, is dark purplish or greenish brown above; pale yellowish below; madreporite pale lemon-yellow.

The smaller specimen agrees well with the larger, except in having all the spines disproportionately smaller, and in lacking visible peractinal plates and large dorsal dermal pedicellariæ; but similar ones occur beneath, on the interradial areas. Minor pedicellariæ form large wreaths on the dorsal spines.

Two specimens (No. 18) were dredged in shallow water in Departure Bay, British Columbia, by Prof. John Macoun and party, of the Canadian Geological Survey, in 1909.

These specimens are probably both young, though the larger is nearly as large as the type of *O. kœhleri,* with which it appears nearly to agree in proportions. It may, possibly, be the young of *O. columbiana,* which comes from the same district; but the smallest undoubted specimens of that species that I have seen have much stouter rays and much larger and less numerous spines, though the rays are scarcely longer, and it has a row of spiniferous peractinal plates. The large dermal dorsal pedicellariæ are similar in the two forms, but relatively smaller and less stout in the young *columbiana.* The minor pedicellariæ are also smaller in the latter and form smaller wreaths on the dorsal spines. Therefore it is more probable that they are distinct, though closely related species. It would certainly be unwise to unite them without intermediate forms.

ORTHASTERIAS GONOLENA Verrill, sp. nov.

Plate LXVII (dorsal side); plate LXVIII, figure 1 (actinal side); plate LXIX, figure 2 (portion enlarged); plate LXXXII, figures 3-3*b*, 4-4*a* (details).

Rays five, of moderate length, rather stout, somewhat angular. Disk small. Radii of the specimen figured, 8 mm. and 68 mm.; ratio, 1:8.5. Radii of a larger specimen, 13 mm. and 83 mm.; ratio, 1:6.4.

Dorsal spines rather long, tapered, obtuse, not much grooved or fluted, well spaced. They form three rows, quite regular in the smaller specimens, less so in the larger. The median row is distinct, having more regular and more numerous spines, though they are not longer. The spines stand singly on rather stout, alternate plates. They are surrounded in the dry specimens by a large subbasal wreath of small minor pedicellariæ attached to the edge of a thick basal sheath. Papular areas unequal; some are very small, others large, with many small papulæ. Superomarginal spines similar to the dorsals in size and form. They form a regular row, one to each alternate plate. No intermarginal spines; interactinal plates are sporadic, spineless, small, compressed, standing edgewise, scarcely visible unless cleaned by potash. The integument is rather thick.

The inferomarginal spines stand two to a plate, placed obliquely in two rows, close to the adambulacrals, but with a row of small, single papulæ between. These spines are about as long as the superomarginals, but not so stout, and they are decidedly flattened distally. There is a wide, conspicuous intermarginal channel, in which papular areas of small size alternate with the plates in a regular row. In this lane or channel are also scattered erect, stout, wedge-shaped pedicellariæ of large size, often nearly as stout as the spines. The lane is crossed by the long, stout, descending apophyses of the superomarginal plates, which meet and overlap the ascending lobes of the inferomarginals, without an intermediate ossicle. The alternate spineless plates have equally large apophyses. The dorsal connective ossicles are stout, nearly as wide as the plates.

The adambulacral spines stand obliquely, two to a plate, erect in the type, nearly equal in length, the inner ones more slender, all distinctly flattened and sometimes slightly grooved distally, except the adoral ones, which are longer, more slender, terete or nearly so.

The dorsal dermal pedicellariæ are few on the type, wedge-shaped. Some very large ones are found on the sides, as mentioned above, and some of the same form and equally large are sometimes found attached to the inner edge of the adambulacral groove, or to the bases

of the spines; these are usually denticulate. Smaller short-ovate major pedicellariæ occur on the interradial areas (see figures).

Specimen described and figured is from off southern California (Professor Ritter, coll. Yale Museum).

I have also studied specimens of this species in the Museum of Comparative Zoölogy from the Gulf of California (No. 1214), eight young, from 35 mm. to 75 mm. in diameter; La Paz (No. 1215), one small; Santa Cruz Island, California (No. 1212), one; Santa Barbara, California (No. 1413), about 150 mm. in diameter; San Diego, California (No. 1825), one.

This species differs from *O. californica* and *O. columbiana*, both of which it resembles, in lacking peractinal spines. Its dorsal spines are not fluted like those of *columbiana*, nor do they have the stout, elevated sheath carrying the pedicellariæ, present in that species; the large wreaths in this are basal. The pedicellariæ are also distinctive. The rays are more angular and the ossicles stouter.

Genus **Distolasterias** Perrier.

Distolasterias (*pars*) Perrier, op. cit., 1896, p. 34. Type, *D. stichantha* Sladen, from Japan. See above, p. 47.

This genus, as restricted to the *stichantha* group, is closely related to *Orthasterias*. It differs mainly in having no interactinal plates, visible externally, at least in our species, even after removal of the dermis by potash, though a rudiment may, perhaps, exist internally. Also in having more numerous rows of dorso-lateral plates and spines, and in having the plates more closely joined, mostly by their own overlapping lobes, with only few small connective ossicles. Thus the papular areas are small and numerous, with papulæ in small groups. The superomarginal and intermarginal lanes are narrow, each with a regular row of small papular areas, with few papulæ. The inferomarginal lane is very narrow, with the papulæ standing singly or in pairs. Alternate superomarginals are not spineless in our species.

DISTOLASTERIAS CHELIFERA Verrill, sp. nov.

Plate LXXXI, figures 1-1*b* (spines and pedicellariæ); plate CX, figures 1, 2 (type).

A good dry specimen of this species (No. 1346) has the radii 10 mm. and 100 mm.; ratio, 1 : 10. A larger one, No. 19, from British Columbia, has the radii 16 mm. and 180 mm.; ratio, 1 : 11.2.

The five rays are long, slender, nearly terete, gradually tapered to unusually slender tips, with a small apical plate.

Dorsal spines are numerous, pretty evenly distributed, and mostly stand singly, arranged apparently in quincunx; or they might be said to form nine alternating rows, with some intermediate. Dorsal median row distinct, but scarcely different in size. The dorsal spines are rather short, for a *Distolasterias,* and often a little clavate and deeply fluted near the obtuse tips. Papular areas are mostly rather large with few papulæ. Minor pedicellariæ are very small and form dense wreaths around the middle of the spines.

Superomarginal spines are like the dorsals, but a little longer; they form a regular row, one to a plate. Inferomarginals rather more slender, two to a plate, mostly flattened and slightly gouge-shaped at the truncate tips, and with large clusters of minor pedicellariæ. Adambulacrals two to a plate, nearly equal, in two equal, regular, divergent rows, slender, not flattened. The proximals and epiorals longer; apical oral pair of spines stouter. The peractinal plates are small and spineless or lacking.

In the lane between the adambulacral and inferomarginal spines there is a regular row of small papular areas, each having usually a single papula. A similar series exists between the inferomarginals and superomarginals.

Dorsal major pedicellariæ are mostly large, elongated, sometimes nearly as stout as the spines, usually decumbent, with spatulate jaws strongly unguiculate with one to three curved denticles at the tip. Some are stouter, erect, more or less ovate. The denticles of the dorsal major pedicellariæ are few, large curved and interlocking, sometimes only one fitting between two on the opposite valve; often two on each; or two on one and three on the other. Similar large ones occur on the sides and on the actinal interradial areas; those of the latter areas are often more elongated and remarkably large.

The adambulacral major pedicelleriæ are more slender, lanceolate, acute.

The type is from Vancouver Island (No. 1346, Mus. Comp. Zoöl.). The larger specimen (No. 19, Geological Survey of Canada) is from British Columbia.

This species is notable for its unusually numerous fluted dorsal spines and very large unguiculate pedicellariæ.

The larger dry specimen mentioned above agrees very well with the type, except in features due to its greater age. The dorso-lateral spines are more numerous and cannot be said to stand in any definite rows; their arrangement is in irregular quincunx, or in irregular oblique transverse series of about five on each side of the slightly

more prominent carinals. The dorso-lateral plates are openly stellate-reticulate, with rather narrow connective ossicles, leaving large angular papular areas with many papulæ. Each plate bears one spine on a raised central boss.

Minor pedicellariæ are very abundant between and around the bases of the spines. Marginal and adambulacral spines are nearly as in the type. No peractinal plates are visible. The specimen is dry and varnished. It was stained dark purple to imitate the natural color.

British Columbia (Geological Survey of Canada, No. 19).

Genus **Urasterias** Verrill.

Plate LXX, figures 1-4.

Urasterias VERRILL, Amer. Journ. Sci., XXVIII, p. 67, 1909. Type, *U. linckii* (M. and T.).

Large starfishes with a loose, openly reticulated dorsal skeleton, composed largely of slender ossicles, with few larger plates, mainly in the interradial or genital areas. Dorsal spines large, mostly isolated on the plates; median radial row usually distinct; elsewhere they are mostly scattered. Superomarginal spines elongated, mostly standing in single rows. No notable actinal plates nor spines. Adambulacral plates diplacanthid or subdiplacanthid.

Some details of the type are figured on pl. LXX, figs. 1-4.

Genus **Parasterias** Verrill, nov. See also p. 53.

Type, *P. albertensis* Ver.

Dorsal and marginal skeleton fairly well developed, reticulated nearly as in typical *Asterias*. Interactinal plates lacking or rudimentary, not showing externally. Adambulacral plates diplacanthid.

PARASTERIAS ALBERTENSIS Verrill, sp. nov.

Plate LVII, figures 1, 2; plate LXX, figure 6.

A five-rayed species with rather depressed rays and openly reticulate structure, the dorsal ossicles being thin and weak, while the papular areas are large and conspicuous. Dorsal spines are not numerous, very small, tapered, obtuse, not capitate, pretty evenly distributed on the ossicles, standing singly and not forming a conspicuous median row.

Madreporite rather large, convex, fine-grained, not encircled by spines. Minute major pedicellariæ, acute-ovate in form, are

sparsely scattered on the papular areas. The distal dorsal spines have thick wreaths of minor pedicellariæ.

There are but two distinct double rows of lateral and ventral spines. The upper one, which appears to be the superomarginal, usually has three spines to a plate proximally but only two distally; the spines are like the dorsals but slightly larger. The lower or inferomarginal row bears two spines to a plate, regularly, the spines being like those above. This row of plates is separated from the adambulacrals by a row of papular areas.

The adambulacral plates have each two slender, divergent spines, which are tapered and subacute and carry numerous acute-lanceolate major pedicellariæ of moderate size; similar pedicellariæ are abundant on the interradial areas and marginal channels.

The radii are 13 mm. and 54 mm.; ratio, 1:4.

Albert Bay, British Columbia (Miss Kate Foote, January, 1887, Yale Museum). # 5537.

This species looks more like the typical species of *Asterias* of the North Atlantic than any other west-coast species known to me. It resembles some varieties of *A. rubens* and *A. forbesi* quite strongly, but the evenly reticulated arrangement of the dorsal plates and spines and the absence of a larger median row give it a characteristic appearance. The lack of interactinal plates and spines is distinctive.

Genus **Allasterias** Verrill.

Type, *A. rathbuni* Verrill.

Allasterias Verrill, Amer. Journ. Sci., xxviii, p. 65, 1909.

Distinguished by the arrangement of the adambulacral spines, in several series, of which one is deeper within the groove on alternate plates. Disk rather large, areolate. Dorsal ossicles numerous, but small, arranged, both on the disk and rays, in a reticulate manner around the papular areas, which are numerous, and bear large groups of small papulæ. Spines numerous, arranged irregularly, or placed around the papular areas, but usually forming a median radial series. Upper marginal plates rather large and stout, so as to form an angular margin, bearing one or several spines larger than the dorsals. Lower marginals not close to the adambulacrals, bearing in the type two or three spines, longer than the upper ones. Actinals rudimentary or lacking. A wide intermarginal channel, with many forficulate pedicellariæ.

The arrangement of the adambulacral spines is peculiar, for while the plates bear alternately two and three spines, the inner spine of the alternate plates is attached deep within the groove on a special lobe of the inner edge of the plate, while the two outer ones stand on the actinal end, nearly in line with the spines of the adjacent actinal plates; thus they seem to form four or five rows. Jaw-plates bear two pairs of apical oral spines, one above the other.

The interradial areas, near the jaws, are without spines and in the dry specimens they are sunken in the form of pits. The position of the genital pores was not determined for lack of alcoholic specimens.

ALLASTERIAS RATHBUNI Verrill.

Plate LXXVIII, figure 2 (details), var. *nortonensis*.

Allasterias rathbuni VERRILL (*pars*), Amer. Journ. Sci., XXVIII, p. 65, 1909, figs. 5, 6, 7 (as varieties).

Asterias rubens ? MURDOCH, Rep. Int. Polar Expedition to Point Barrow, p. 159, 1885 (*non* Linné).

Rays five, broad at base and rapidly tapering to acute tips. Radii, 25 mm. and 100 mm.; ratio, 1:4. Small major pedicellariæ are abundant all over the dorsal and lateral surfaces.

Dorsal skeleton rather feeble, composed of a great number of small ossicles, arranged in an openly reticulated manner, so that the texture is rather soft and flaccid, in alcohol. The dorsal papular areas are numerous and contain many small papulæ. Disk rather broad, but probably abnormally so in the dried specimens, owing to the flattening when soft.

The whole dorsal surface is conspicuously areolate or reticulate, the areolations mostly 1.5 mm. to 2 mm. broad. The dorsal spines are very small and numerous, sometimes almost like round or capitate granules, being scarcely higher than thick, but in other examples clavate or partly acute; they are scattered or arranged in single rows on all the ossicles, so as to form a border around the papular areas; toward the sides of the rays they are distinctly longer and mostly clavate or subacute.

The superomarginal spines form a wide band of small, crowded spines, five to ten or more on a plate. They are mostly larger and longer than the dorsals, and two or three times as long as thick, mostly cylindrical or clavate, sometimes gouge-shaped. Below this band there is a broad intermarginal channel with large papular areas and numerous rather large, pointed major pedicellariæ. This channel rapidly widens at the bases of the rays.

The lower marginals form a double row, mostly two to a plate; they are similar to the upper ones, but longer and mostly more clavate, often with slightly gouge-shaped tips. Between the upper and lower marginals, at the bases of the rays, a short intermdiate row of ossicles is sometimes interpolated, and defined by a row of small papular pores; their spines are like the lower marginals, and mostly stand singly. Synactinal spines are lacking; there is a wide, naked channel between the adambulacrals and inferomarginals.

The adambulacral spines are peculiarly arranged, and look as if in four rows, in adult specimens. Each plate bears two spines, or alternately two and three; but on the alternate plates, having three spines, the inner spine is set on the inner edge of the plate, deep within the groove, while its outer spines are at the summit, nearly but not quite in line with the spines of the alternate plates. The outer of these spines are situated further back, at the outer end of the plates. These spines are not very slender, either tapered or clavate, mostly obtuse, as long as the marginals or longer, and more slender. Many of the inner ones bear small, acute major pedicellariæ; the outer ones have a small cluster of minor pedicellariæ.

The apical jaw-plate bears an inner close pair of stout, tapered spines, low down within the mouth, and a similar upper pair at the upper margin; both pairs bear several large major pedicellariæ.

Major or forficulate pedicellariæ are usually everywhere abundant, scattered over the surface, between the dorsal, marginal, and actinal spines, and especially on the lateral channels and interradial areas. The larger ones are compressed, rather large, lanceolate or acute-triangular, with a sharp or acuminate apex. Those that are scattered on the dorsal surface are smaller, unequal in size, but similar in form, though less acute. The larger and longer ones measure mostly about 1.00 mm. × 0.33 mm. to 0.37 mm.; the stouter ones, 0.87 mm. × 0.37 mm. and 0.72 mm. × 0.39 mm.

Minor pedicellariæ, of very small size, are attached to many of the spines in small groups, and are also found scattered on the dorsal papular areas.

The madreporic plate is large, convex, with numerous gyri.

Dedicated to Dr. Richard Rathbun of the U. S. National Museum.

The type specimens are from Maloska (Professor Kincaid).

This species is so different from any other known to me from this region that no detailed comparisons seem necessary. Its finely and regularly areolated surface, flaccid, reticulated dorsal skeleton, and small spines will serve to distinguish it at a glance.

The arrangement of the adambulacral spines is so peculiar that it should, even on that account alone, form the type of a genus. But it is also peculiar in the structure of the dorsal skeleton, the character of the marginal spines, etc.

The only other species known to me, besides the following four, described as having a similar arrangement of a row of spines within the groove, is *A. versicolor* (Sladen), from off Kobe, Japan. In that species the alternate plates bear only one spine, and the dorsal and lateral spines are larger, much less numerous, and differently arranged. It evidently belongs to the same genus.

Besides *A. versicolor,* there is another species, *A. amurensis* Lütken, as *Asterias,* from further north, on the Asiatic coast, and also recorded from Yokohama by Sladen, that must bear considerable resemblance to our species, though the dorsal and upper marginal spines are fewer and longer. Lütken, however, does not mention any such peculiar arrangement of the adambulacral spines as is found in this group. I have had no opportunity to study his species.

A small Korean starfish, described by Sladen (1878, p. 432), under the name of *Asterias rubens,* var. *migratum,* probably belongs to this genus, and should be called *Allasterias migrata,* but its immaturity (greater radius of the larger specimen, 16 mm.) renders it impossible to determine whether it be distinct from the other known species, until a series can be studied.

ALLASTERIAS RATHBUNI NORTONENSIS Verrill.

Plate LXXVIII, figure 2 (details of type); text-figures Nos. 8, 9.

Allasterias rathbuni, var. *nortonensis* VERRILL, op. cit., 1909, p. 66, fig. 7.

Rays five, broad at base, depressed, acute. Radii of the type are 22 mm. and 82 mm.; ratio, 1 : 3.8.

The dorsal spines are numerous, pretty evenly spaced and scattered over the rays and disk on the openly reticulated, slender ossicles. They are partly blunt, cylindric, and partly clavate, but not strongly so, rather longer than in the typical form. Papular areas are large, with many small papulæ and scattered small dermal pedicellariæ. Madreporic plate large and strongly convex. The dorsal spines bear but few minor pedicellariæ. Some larger acute major pedicellariæ occur among the spines.

The adambulacral spines stand mostly two and three to a plate in alternation. The inner or furrow spines are elongated, tapered, subacute and often bear a cluster of small major pedicellariæ. The outer

ones are a little stouter and less acute, mostly not quite so long. They usually bear a small group of minor pedicellariæ on the outer side.

The inferomarginal spines mostly stand two or three to a plate, forming a pretty regular double row. They are much stouter than the adambulacrals and not quite so long; many are a little flattened or pinched up at the tip, and often slightly gouge-shaped.

The superomarginals are more numerous and shorter, of similar shapes. Near the disk they often stand four to six on a plate, crowdedly. There are no peractinal plates. Major pedicellariæ are numerous on the sides and actinal surface. The larger of these are

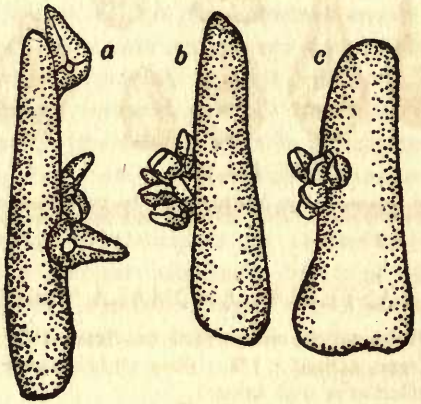

FIG. 8.

Allasterias rathbuni nortonensis Ver. No. 7621, U. S. Nat. Mus. Spines; *a*, intra-ambulacral; *b*, outer-adambulacral; *c*, inferomarginal. × 20.

elongated, acute or acuminate in profile, with the valves mostly narrow spatulate; some of them are dentate at the tips, with two or three curved teeth. The larger ones measure 0.67 mm. × 0.30 mm.; 0.67 mm. × 0.27 mm.; 0.65 mm. × 0.25 mm.; 0.57 mm. × 0.23 mm. Many are smaller, short and thick, sometimes as broad as long. These measure 0.50 mm. × 0.30 mm.; 0.40 mm. × 0.27 mm.; 0.35 mm. × 0.40 mm.; and smaller.

The type, and the only specimen seen, was from Norton Sound (coll. Murdoch, No. 7621, U. S. Nat. Mus.). This presents several rather strongly marked characters, which might be considered specific if persistent in a large series of specimens. But with the small number of specimens available for study it seems better to consider it a subspecies at present. Very likely the species may prove to be a very variable one. The characters that seem most important are the smaller size and stouter form of the major pedicellariæ, and

the different forms of the minor pedicellariæ. The dorsal and marginal spines are longer than in the typical form, and the papulæ are more numerous.

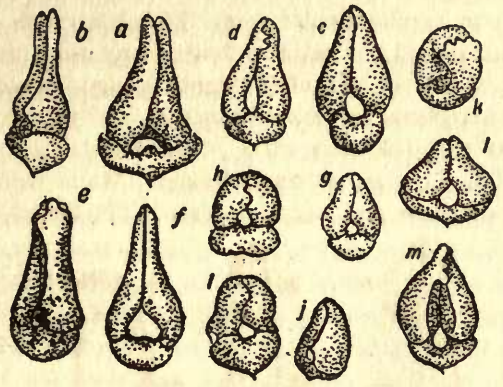

FIG. 9.

Allasterias rathbuni nortonensis Ver. Pedicellariæ from the axillary or actinal interradial areas; *a-c*, acute lanceolate forms; *d*, *e*, *m*, the same with the valves spatulate and dentate; *g-l*, small short forms. × 32.

ALLASTERIAS ANOMALA Verrill.

Plate LIX, figure 2 (type, actinal side); plate LX, figure 2 (type. dorsal); plate LXIX, figure 5 (type, actinal × 5⅝); plate LXXVII, figure 3; plate LXXVIII, figures 3, 4 (pedicellariæ and spines).

Allasterias rathbuni, var. *anomala* VERRILL, op. cit., 1909, p. 66, figs. 5, 6.

Rays five, broad at base, regularly tapered to rather acute tips, and margined on the sides with a fringe of superomarginal spines. Radii of the type, 23 mm. and 87 mm.; ratio, 1 : 3.8. Breadth of rays at base, 29 mm.

The dorsal ossicles are slender and loosely reticulated, leaving large papular areas, with numerous papulæ. The dorsal spines are short, small and numerous, not crowded, clavate and capitate. They mostly stand isolated on the ossicles around the papular areas, often forming imperfect circles or polygons having twelve to twenty spines in the groups, so that they present a somewhat reticulated arrangement. A median radial row is distinct, due to the increased number of spines, not to their larger size.

The madreporic plate is large, round, and convex, without any special spines around it.

The superomarginal spines form a conspicuous marginal fringe, owing to their numbers rather than to their size. They are short,

stout, enlarged distally, truncate, and mostly grooved or gouge-shaped at the end. They are much crowded and stand mostly five or six to a plate.

The inferomarginals are similar in form, a little longer, and mostly stand two or three to a plate, in oblique groups. There is a well marked channel between these and the superomarginals, but no intermarginal rows of spines. A similar regular channel separates the inferomarginals from the adambulacrals. These channels are both occupied by large papular areas, with clusters of small papulæ, and by rather large, acute major pedicellariæ.

The adambulacral spines stand mostly two and three to a plate, alternately, every other plate bearing a rather long, tapered, furrow-spine. Most of their other spines, on the actinal side, are stout, enlarged distally, and grooved or gouge-shaped on the outer side.

The minor pedicellariæ are few and very small. They are entirely lacking on most of the dorsal spines, and very few occur on the marginal spines.

The major pedicellariæ are frequent both on the actinal and on the lateral areas, but not abundant. They are few and scattered on the dorsal surface. The larger are compressed, acute-lanceolate, some more acute than others; the smaller ones are short-lanceolate or ovate.

The jaws are elongated and rather compressed. The two upper apical spines are stout and bear small clusters of acute major pedicellariæ; the lower ones are much smaller, bent, acute. There are two spaced pairs of stout epiorals.

The type is from St. Michael, Alaska (L. M. Turner, 1874-76, No. 3821, U. S. Nat. Mus.).

ALLASTERIAS FORFICULOSA Verrill, sp. nov.

Plate LXXXIII, figures 3-3*c* (details); plate LXXXIV, figure 1, *a-h* (pedicellariæ); text-figures 10, 11.

Asterias amurensis IVES, Proc. Acad. Nat. Sci., Philad., for 1891, p. 212, plate VIII, figures 5-8 (*non* Lütken).

Rays five, rather short, wide at base, depressed, tapering rapidly, rather acute, bordered by a fringe of superomarginal spines. Radii, 20 mm. and 58 mm.; ratio, about 1:3; breadth of rays at base, 21 mm.

The dorsal spines are well spaced, rather scattered, but on the sides of the rays forming pretty evident radial rows; median row distinct but not prominent. They are short, stout, about twice as

high as thick, mostly cylindric or slightly clavate, obtuse, but some are acute. They are mostly surrounded by small wreaths of very small minor pedicellariæ.

The dermal surface is notably smooth and even. The papular pores are very small, not very numerous. Very acute lanceolate major pedicellariæ, of diverse sizes, abound on the surface.

The superomarginal spines stand obliquely, mostly two or three on a plate. They are longer than in the allied species, rather stout, much flattened, and often a little grooved on one side distally, but not thickened as in *A. anomala.*

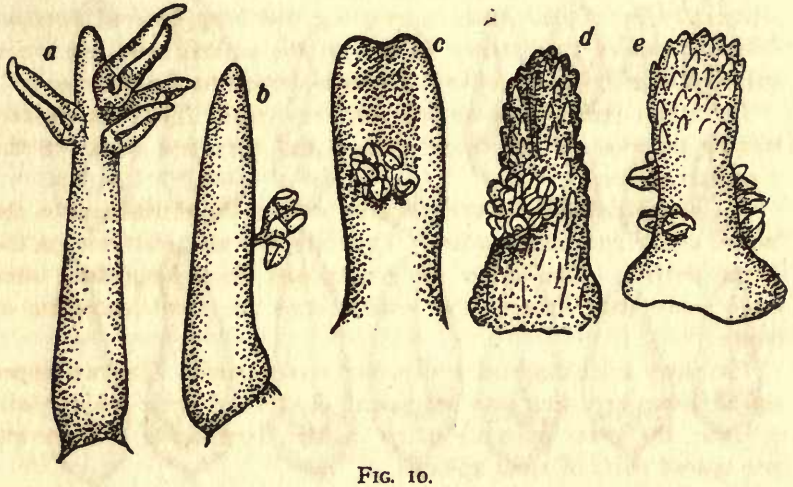

FIG. 10.

Allasterias forficulosa Verrill. No. 1183, M. C. Z. Spines; *a*, intra-ambulacral; *b*, outer-adambulacral; *c*, inferomarginal; *d*, superomarginal; *e*, dorsal. × 20.

The inferomarginal spines are very similar in size and form; they stand two to a plate, in a regular double row. A wide, smooth channel separates the two series of marginal spines, and a similar channel separates the adambulacral series. These channels have numerous rather large, very acute, lanceolate pedicellariæ, and many small papulæ. The marginal spines all bear clusters of small minor pedicellariæ on the outer surface.

The adambulacral spines appear crowded, in about three rows. They mostly stand alternately, one and two to a plate. The inner or furrow series stand erect. They are long, slender, very acute, and bear clusters of major pedicellariæ of diverse sizes, but mostly very acute. The outer spines are shorter, stouter, obtuse, and mostly bear clusters of very small minor pedicellariæ on the outer side.

The larger pedicellariæ of the lateral channels (*o-r*) are very acute-lanceolate and compressed. The larger ones of the dorsal surface (*a, c, d, f*) are similar in size and form, but some are stouter and less acute (*b, h, k*), and there are with them many of smaller sizes (*i, j, l, m, n*). The larger and longer ones measure 1.00 mm. × 0.33 mm.; 1.00 mm. × 0.37 mm.; the stouter ones, 0.87 mm. × 0.37 mm.; 0.72 mm. × 0.37 mm.

The type was from Japan, probably Sagami Bay (No. 1183, Mus. Comp. Zoöl.).

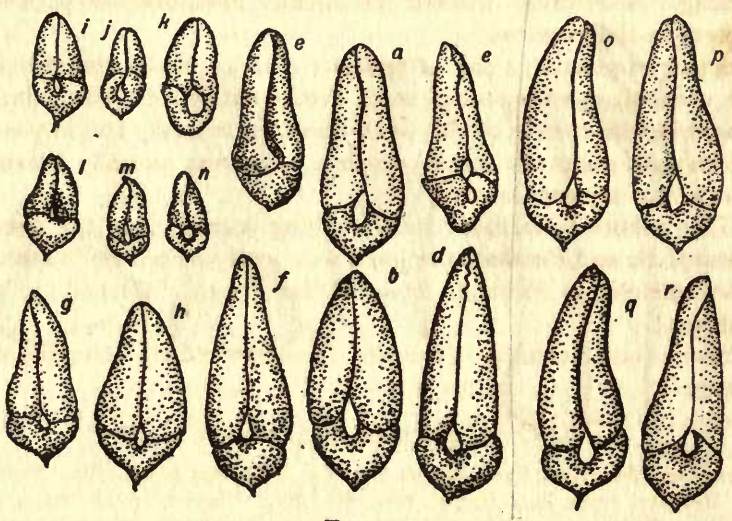

FIG. 11.

Allasterias forficulosa Verrill. No. 1183, M. C. Z. Pedicellariæ; *a-n*, major pedicellariæ from the dorsal surface; *o-r*, the same from the actinal interradial region (axillary), and marginal lanes. ×32.

The Japanese species figured, but not described, by Ives (1891) appears to be either this or a very closely related species of the same genus. It is very different from Lütken's species.

This species, though not known from the American side, is introduced here for comparison with *A. rathbuni*, to which it is certainly pretty nearly allied. It has fewer adambulacral spines, larger and longer dorsals and marginals, and much more numerous, larger, and more acute major pedicellariæ. It is, no doubt, related to *Allasterias versicolor* (Sladen), also from Japan, as mentioned above.

The latter has far less numerous dorsal spines, and the major pedicellariæ are much stouter and less acute.

Subfamily PYCNOPODIINÆ.

Family *Pycnopodidæ* (*pars*) STIMPSON, op. cit., 1861, p. 261.
Family *Pycnopodidæ* FISHER, op. cit., 1906*b*, p. 136 (with *Rathbunaster* F.).

Disk broad and flat, with numerous rays, increasing with age by the interpolation of new rays by budding in successive pairs bilaterally, at least in the type.

Dorsal skeleton feebly developed, the ossicles in part united only by thick integument. Spines few, scattered. Pedicellariæ usually large and numerous, of two kinds. Adambulacral plates mostly monacanthid. Marginal plates distinct. Interactinal plates small or lacking. Body-cavity without the circular disco-brachial partition, present in Heliasterinæ.

A pair of gonads; a pair of retractor muscles; and a stomach-lobe for each ray. Interbrachial septa feebly developed. Podia large, mostly in four rows in adults, often biserial proximally and in young. Ambulacral plates not much crowded, sometimes partially alternate in rays that are bent laterally.

This subfamily includes, among living species, only the genera *Pycnopodia* and *Rathbunaster*, each with a single species. *Rathbunaster californicus* Fisher is from off San Diego, California, in 339 fathoms.

Some fossil starfishes from the Devonian closely resemble this group.

Genus Pycnopodia Stimpson.

Pycnopodia STIMPSON, Proc. Boston Soc. Nat. Hist., VIII, p. 261, 1861. Perrier, Révision, Arch. Zool. Expér., IV, p. 353, 1875. Viguier, op. cit., VII, p. 109, pl. V, figs. 11, 12, 1878 (odontophore, etc.). A. Agassiz, North American Starfishes, p. 100, pl. XIII, 1877 (structure of skeleton). Sladen, Voy. Challenger, XXX, pp. XXXIX, 560, 830, 1889. Ritter and Crocker, Proc. Wash. Acad. Sci., II, p. 247, plates XIII, XIV, 1900 (increase of number of rays). Loeb, Publ. Univ. Calif., Physiol., II, pp. 5-30, 1904 (experiments in hybridization).

Disk large, covered with a thick, soft integument, in which are few, mostly detached, elliptical ossicles, some of which bear slender isolated spines. Clusters of minor pedicellariæ are also scattered over the surface, and in large specimens there are usually many large, scattered major pedicellariæ. Rays variable with age, up to twenty to twenty-four in the adult. Their increase is by the interpolation of new rays, usually symmetrically in pairs, between the older ones. Superomarginal and inferomarginal plates are ventral. They form two regular parallel rows, close together, united by the

broad descending apophyses of the upper plates, with large intervening papular areas. The upper plates are large, deeply three-lobed, and usually bear a single large spine. The lower plates are rather smaller, less strongly lobed, and usually bear two large divergent spines. Adambulacral plates are crowded, oblique, bilobed distally, and each bears a single slender spine. Adoral carina is long, containing twelve or more pairs of contingent ossicles. Two large and two smaller peroral spines. Oral area large.

This genus is peculiar to the west coast of North America. It contains only a single species, which is one of the most common and most characteristic littoral and shallow-water starfishes, from Puget Sound to Yakutat, Alaska. It lives among stones at and below low-tide mark.

PYCNOPODIA HELIANTHOIDES (Brandt) Stimpson.

Plate XXIX, figure 1; plate XXX; plate XXXI, figures 1, 2; plate LXXIII, figure 1; plate LXXIV, figures 1-3*a* (young), figure 6 (pedicellariæ); plate LXXXVIII, figures 7-7*d* (details); text-figure No. 2 (pedicellariæ).

Asterias helianthoides BRANDT, Prod. Desc. Anim., Mertens, p. 71, 1835. Stimpson, Journ. Bost. Soc. Nat. Hist., VI, p. 89, 1857 (no description).

Pycnopodia helianthoides STIMPSON, Proc. Boston Soc. Nat. Hist., VIII, p. 261, 1861. Verrill, Trans. Conn. Acad. Sci., I, pp. 324, 326, 327, 1867 (no description). Perrier, Révision, Arch. Zool. Expér., IV, p. 353, 1895 (no description). A. Agassiz, N. Amer. Starfishes, p. 100, pl. XIII, 1877 (structure). Whiteaves, Trans. Royal Soc. Canada, IV, p. 116, 1887 (distribution). Ritter and Crocker, Multiplication of Rays and Bilateral Symmetry, Proc. Wash. Acad. Sci., II, pp. 247-274, pls. XIII, XIV, figs, 1-13, 1900. Clark, Proc. Boston Soc. Nat. Hist., XXIX, p. 329 (no description).

Disk broad and soft. Rays in the adult are usually from eighteen to twenty-four, most frequently an even number, but those with odd numbers are not rare. I have seen them with fifteen, seventeen, nineteen and twenty-one rays. In the young the number varies from six to twelve or more. The increase is brought about by the budding in of successive pairs of new rays, in interradial angles situated symmetrically, as shown by Messrs. Ritter and Crocker.[1] Sometimes odd new rays appear in other places. (See also our pl. XXXI.) The radii in the rather small dry specimen figured on our pl. XXIX, are 75 mm. and 182 mm.; ratio, 1 : 2.42.

The rays are rather slender and regularly tapered, covered dorsally by a soft skin, which bears, chiefly toward the ends of the rays, a few scattered, slender spines attached to slender, detached ossicles. On

[1] Proc. Wash. Acad. Sci., II, p. 247, pl. XIV, 1900.

the disk some of the ossicles may unite into a feeble network. Thick clusters of minor pedicellariæ are also scattered over the dorsal membrane. In our larger specimens (see pl. xxx), there are also many large major pedicellariæ scattered over the dorsal integument, but they are sometimes entirely lacking in young ones, up to 125 mm. in diameter. They are compressed, long-ovate in outline, obtuse or subacute, not dentate, often exceeding the spines in diameter (text-fig. 2).

The dorsal spines are sometimes partly short and obtuse, scarcely longer than thick; most are long and slender, cylindrical or tapered, rarely subclavate. They are often striated or grooved at the tip, but more commonly are regular and subacute. They are more numerous on the distal part of the rays, where they become very slender and bear a thick wreath of minor pedicellariæ at about mid-height. Those on the disk have the wreath of pedicellariæ around the base. The superomarginal spines are similar to the dorsals, but a little larger; they generally stand singly on alternate plates, and bear thick wreaths of pedicellariæ. The inferomarginal spines are longer and stouter, often slightly enlarged at both ends, and mostly flattened and obtuse or subclavate at the tip, two to a plate.

The adambulacral plates are strongly compressed; each bears a single, very slender, slightly tapered, terete spine. Major pedicellariæ of different sizes also occur on the adambulacral plates, with pedicels. Some of these are even larger than those on the dorsal surface. They are similar in form, but are often more oblong-ovate. The two apical peroral spines are stouter and much shorter than the adorals; the side-spine is short and stout. The epiorals are long and slender, tapered, longer than the adorals. The adoral spines are decidedly longer than those more distal.

The ambulacral feet are in four regular rows in half-grown and mature specimens, except proximally and distally, where they are nearly biserial. In quite small ones they are in two nearly regular rows.

The color, in life, is often bright red to reddish brown, but varies from yellow, orange, and carmine to violet.

Three large specimens from Puget Sound (coll. Professor Kincaid, Mus. Comp. Zoöl., No. 1908) have seventeen, eighteen, and twenty rays, respectively. One much smaller specimen, from the same place, has seventeen rays; and one about eight inches (200 mm.) in diameter has eighteen rays. One about six inches (150 mm.) in diameter has only twelve rays. Thus the number of rays does not

depend very closely on the size. One of the largest of this lot has the radii 70 mm. and 275 mm. Some young specimens, not more than 30 mm. in diameter, already have sixteen rays; while others, 200 mm. in diameter, have no more.

It is said, on good authority, to become over four feet in diameter. In that case, it is probably the largest starfish known. The largest that I have seen are over two feet in diameter. Large specimens are hard to preserve, and for that reason are seldom collected.

TERATOLOGY.

The budding in of new rays does not always proceed in a regular bilateral manner by pairs. I have studied several young specimens in which, in addition to the regular pairs, one or two new rays had appeared irregularly in different places. If one odd ray appears it gives rise to an odd total number of rays; for if the young start with six rays and a pair of new rays appears each time, the final number must be even. One specimen before me, eight inches in diameter, has nineteen equal and regular rays, with a pair of small budding rays placed regularly. Such an individual may have had seven rays at first instead of six. In most cases the first pair of interpolated rays appears either side of a single ray, with five rays on the other side. This indicates that the original number of rays in the young is normally six. But in the case just cited there are five posterior rays, as usual, while there are fourteen (seven pairs) in front, indicating that at first there may have been two front rays, or seven altogether. This may be the manner of origin of some specimens with odd numbers of rays. But I have seen no very young ones of this sort. Should one bud be suppressed, or two buds appear together on one side, in place of one, the final result would be the same.

I have studied very young ones in which one bud is suppressed (see pl. LXXV, fig. 1). One young example (pl. LXXV, figs. 3, 3*a*) has the madreporite much larger than usual. It has an oblong disk and eighteen somewhat unequal rays. It looks as if about to divide autotomously. Its disk is 15 mm. by 12 mm. in diameter. The arrangement of the rays and new buds in this specimen is peculiar and anomalous. Three very small rays, nearly identical in size and structure, are developing simultaneously at three places. Two of these are in the normal position, and separated by seven nearly equal rays. Then follow, on one side, two larger rays succeeded by a small, extra, budding ray; on the other side no such bud appears.

Between the extra bud and the normal one, on the other side, there are six normal, equal rays, making fifteen normal rays, plus three budding ones.

This arrangement does not conform to any regular rule. The extra bud is not due to replacement of a lost ray, for it originated like the others. Before it appeared, this end of the body must have had eight equal rays, which would have been abnormal, for five would be the regular number. The interpolation of the new extra bud may have been due to a tendency to resume an odd number of rays at this end, which is the usual condition. The arrangement may be formulated as follows, letting the figures represent normal rays and the letters budding rays. If the extra bud (*b*) is simply adventitious, the arrangement would be thus:

$$\text{I}\ \frac{2\ 3\ 4\ a\ 5\ 6\quad 7\ 8}{2\ 3\ 4\ a\ 5\ 6\ b\ 7\ 8}.$$

If the bud (*b*) be for regulation purposes it would stand thus:

$$\text{I}\ \frac{2\ 3\ 4\ a\ 5\ 6\ 7\ 8}{2\ 3\ 4\ a\ 5\ 6\ b\ 8}\ 9.$$

In this case the bud would pair with ray 7. But this would give this end of the starfish nine rays, instead of the normal number, five. (See pl. LXXV, figs. 3, 3*a*.) Probably autotomy would have taken place later, followed by a regulation process by which the usual number and arrangement of rays would have been resumed in one or both parts.

The budding in of rays in this species may continue till late in life. A specimen studied by me, nine inches in diameter, having nineteen fully developed rays, had a pair of small, equal budding rays in the normal position, except that there were fourteen rays on the budded side, instead of an odd number. There were five, as usual, on the other side.

A careful study of the living young of this species should be made, where it is abundant, to ascertain more fully its complete history during growth.

In some cases the ambulacral plates are not strictly opposite, and may even appear to be alternate, when the rays are strongly bent sidewise, owing to their loose articulations. In a few cases the number of these plates is not the same on the two sides of the groove, for a short distance; apparently due to the irregular interpolation of an extra plate on one side only, here and there. When this occurs

the plates must become alternate, locally. This recalls the regular alternation of these plates in many paleozoic fossil starfishes.

The species has an extensive range, from Monterey and Tomales Bay, California, to Dutch Harbor and Yakutat, Alaska. According to Professor Ritter, it was very abundant at the latter place on a rocky reef exposed at low tide, while the young were found adhering to *Laminaria*. It is also very abundant at Sitka and in Puget Sound.

Gulf of Georgia (Whiteaves); Gulf of Singio and California (Perrier); Puget Sound and Tomales Bay (Stimpson); Port Townsend, Puget Sound, abundant (Clark). It occurs at low tide and in shallow water, on rocks.

I have also examined specimens from near Monterey, California; Tomales Bay; Victoria; Puget Sound (Kincaid); Vancouver Island (Canadian Geological Survey); Queen Charlotte Islands, etc.

It was collected by the Harriman Expedition at Sitka, Dutch Harbor, and Yakutat, Alaska.

Family *PEDICELLASTERIDÆ* Perrier (*pars*).

Pedicellasteridæ SLADEN, op. cit., 1859, p. 556.

As adopted by Sladen, this family included only the genus *Pedicellaster*. It was distinguished from Asteriidæ only by the arrangement of the podia or "sucker-feet" in two rows, instead of four. More recently Perrier has added the genus *Gastraster*, which has some of the podia in four rows.

Genus **Pedicellaster**.

Type, *P. typicus* M. Sars.

Pedicellaster M. SARS, Oversigt over Norges Echinod., p. 77, 1861. Sladen, op. cit., 1859, p. 557.

Small, delicate starfishes with a reticulated dorsal skeleton, bearing slender spinules; two rows of similar marginal spines. Adambulacral spines usually diplacanthid, rarely triplacanthid, or partially so. Minor pedicellariæ on dermis, similar to those of *Leptasterias*. Major pedicellariæ often lacking. Rays five or six; sometimes eight.

PEDICELLASTER TYPICUS M. Sars.

Pedicellaster typicus M. SARS, op. cit., 1861, p. 77, pl. IX, figs. 9-17, pl. X, figs. 1-10. Danielssen and Koren, Norske Nordhavs-Exped., Zool., XI, Asteroidea, pp. 36-40, 1884. Sladen, op. cit., 1889, p. 557.

Pedicellaster palæocrystallus SLADEN, Ann. and Mag. Nat. Hist., ser. 5, vol. v, p. 216, 1880. Duncan and Sladen, Mem. Echinod. Arctic Sea, W. of Greenland, p. 34, pl. II, figs. 22-26, 1881.

A single small specimen of this delicate, five-rayed species (diameter, 16 mm.) occurred in a lot of other small starfishes sent by the National Museum, No. 6123. It was from the Arctic coast of Alaska, near Icy Cape, in 10 to 15 fathoms, mud and sand (Smith coll.), through W. H. Dall, 1874.

This species is, therefore, circumpolar. It has been taken off Greenland, Grinnell Land, Cape Fraser, Nova Zembla, Beeren Island, etc., and extends southward to the Norwegian coast and to the Gulf of St. Lawrence. Its bathymetrical range is from 15 to 620 fathoms.

Order **SPINULOSA** Perrier.

Stelleridæ Spinulosæ PERRIER, Nouv. Arch. Mus. Hist. Nat., VI, p. 154, 1884.
Spinulosa PERRIER, Expéd. Trav. et Talism., pp. 27, 138, 1894.
Phanerozonia and *Cryptozonia* (*pars*) SLADEN, Voy. Chall., XXX, p. xxiii, 1889.
Spinulosa FISHER, op. cit., 1911*b*, p. 251 (table of known families).

This order, established by Perrier, includes cryptozonate (rarely subphanerozonate) starfishes which usually have but two rows of ambulacral feet (four in *Diplopteraster*); ambulacral plates not crowded; and generally a reticulated or imbricated dorsal skeleton, but rarely, if ever, true paxillæ. The ossicles are sometimes isolated or vestigial in deep-sea genera. The pedicellariæ are generally lacking. When present, they are neither forcipulate nor forficulate. They may be pincer-like, with two or more simple valves, and are always dermal. The marginal plates are nearly always small, and sometimes indistinct. The lower ones are usually the larger. They never form a thick, rigid margin; the margin may be acute or rounded. Papulæ may occur both on the dorsal and on the actinal surfaces, but they are restricted to the dorsal surface in most families.

The odontophores are adambulacral of various forms. The ambulacral grooves are usually narrow. The ambulacral feet always have a terminal sucker. The ambulacral ampullæ may be single or double.

Perhaps the structure of the pedicellariæ is the most positive character for separating certain genera of this group from some of the aberrant Forcipulosa.

A large number of the genera do not have free-swimming larvæ, but are known to carry their eggs and larvæ attached about the mouth, or otherwise, or in a marsupial pouch (*gonocodium*), until

they become true starfishes, large enough to care for themselves.[1] This habit is usually associated with the lack of pedicellariæ. It is conducive to the formation of local varieties. The order may be conveniently divided into two suborders:

I. **AVELATA** Verrill.
II. **VELATA** Perrier.

Suborder **ALVELATA** Verrill, nom. nov.

This includes the more typical forms in which there is no dorsal, tent-like marsupial chamber for the protection of the eggs and young. The spines are either all free, or partially or wholly webbed together into groups, as in Solasteridæ, in which the groups of adambulacral spines form transverse combs completely webbed together, and the dorsal spinules are partially so.

It includes the following families, represented on the Northwest coast in shallow water:

Family *ECHINASTERIDÆ.*
Family *SOLASTERIDÆ.*
Family *MITHRODIIDÆ.*
Family *ASTERINIDÆ.*

Also the following extralimital or deep-sea families, besides other smaller groups:

GANERIIDÆ, Patagonian; Antarctic.
ACANTHASTERIDÆ, Tropical; Panamic.
PYTHONASTERIDÆ, Deep Sea.
KORETHRASTERIDÆ, Deep Sea.
MYXASTERIDÆ, Deep Sea.

Suborder **VELATA** Perrier.

This group includes only the family Pterasteridæ. It is remarkable for having most of the spines webbed together in clusters and for the remarkable development of a dorsal membrane, more or less completely uniting the parapaxillæ together, forming a dorsal marsupial pouch or gonocodium in which the eggs and young are carried.

M. Perrier, in his later works, has separated the Pterasteridæ as an order (Velata). This may be overestimating the importance of

[1] This is the case with the genera *Henricia, Solaster, Pteraster, Hymenaster,* and others.

the peculiar characters of the group. The Velata must, however, be regarded as a highly specialized group, or suborder, differing in many respects from all other starfishes. The Pythonasteridæ seem to me more nearly allied to Solasteridæ.

The family Valvasteridæ, referred to Spinulosa by Fisher, seems to me to belong rather to Valvulosa, among the Phanerozona. It is not represented on the west coast.

Family *ECHINASTERIDÆ* Verrill (restricted).

Echinasteridæ Verrill (*pars*), Trans. Conn. Acad. Sci., I, p. 343, 1867. Perrier (*pars*), Révis. Stell., Arch. Zool. IV, pp. 299, 358, 1875.

Echiniasterinæ Viguier, Arch. Zool. Expér. et Gén., VII, p. 123, 1878 (structure).

Echinasteridæ Sladen (*pars*), Voy. Chall., XXX, p. 535, 1889. Bell, Catal. Echinod., pp. 23, 95, 1890. Perrier, Etoiles de mer, Nouv. Arch. Mus. Nat. Hist., VI, p. 164, 1884; Exp. Trav. et Talism., pp. 28, 141, 1894. Ludwig, Fauna Arctica, I, p. 472, 1900. Fisher, op. cit., 1911*b*, p. 258 (analytical table of known genera, p. 259).

Dorsal skeleton usually formed of small, sometimes overlapping, reticulated or areolated ossicles; sometimes they form longitudinal radial rows. Median dorsal row is often indistinct. Upper marginals small, often not specialized. Inferomarginals usually distinct. One or more interactinal rows are usually present. Dorsal and marginal spines may be large and isolated or minute and clustered, but not truly paxilliform. They are often covered with a distinct, thick, dermal membrane, which may contain calcareous granules.

The ambulacral ampullæ are usually single, one to each tube-foot.

Ambulacral grooves narrow. Adambulacral spines small, two or several to a plate, either in longitudinal or in transverse groups. No pedicellariæ known.

The most prominent genera are *Echinaster* and *Henricia*, both of which occur on the Northwestern coast.

Genus **Poraniopsis** Perrier.

Poraniopsis Perrier, op. cit., 1891, p. 105, pl. X, figs. 2*a*, 2*b* (type *P. echinaster* Perrier). Fisher, 1910, p. 568; 1911*b*, p. 260.

Lahillia de Loriol, 1904, p. 32, pl. III, figs. 1-1*g* (preoccupied).

Alexandraster Ludwig, 1905, p. 210, pl. XV, figs. 79, 80; pl. XXXI, figs. 181-183; pl. XXXII, fig. 184.

Ortmannia de Loriol, op. cit., 1906, p. 78.

Form is five-rayed, stellate. Surface covered with a thick skin. Abactinal ossicles spinose, slender, forming an open reticulation with

wide papular areas and numerous papulæ. Papulæ lacking on actinal side, present between marginals. Adambulacral plates bear two spines; none in the furrow. Pedicellariæ unknown. Madreporite an independent plate.

PORANIOPSIS INFLATA Fisher.

Alexandraster inflatus Fisher, op. cit., 1906, p. 300.
Poraniopsis inflata Fisher, 1911*b*, p. 261, pl. lviii, figs. 7, 7*a*; pl. lxiii, figs. 1, 2; pl. cxii, fig. 1.

Form stellate, with five short, thick, tapered rays. Radii of the type, 23 mm. and 60 mm.; ratio, 1 : 2.6. Dorsal spines large, 3 mm. to 6 mm. high, acute, usually one at each angle of the large papular areas, forming altogether about seven imperfect rows in the type, not including the inferomarginals and those usually present on the interactinal plates. Adambulacral spines two to a plate, grooved, as are usually, also, the interactinal spines, when present. The plates and spines are covered with thick membrane.

Recorded by Fisher from seventeen localities, in 26 to 159 fathoms, from Oregon to San Diego, California.

It was not in the collections received from farther north. Dr. Fisher described another form, from deeper water (334 to 600 fathoms), as *P. inflata flexibilis* Fisher.

Genus **Echinaster** Müller and Troschel; includes **Othilia** Gray.

Stellonia (*pars*) Nardo, Oken's Isis, p. 716, 1834. Agassiz, Prod., p. 191, 1835.
Echinaster (*pars*) Müller and Troschel, Monatsber., Berlin Wiss. Akad., April, 1840, p. 102; Wieg. Arch., 1840 (*non* Gray); Syst. Aster., p. 22, 1842 (*pars*).
Othilia Gray, Ann. Mag. Nat. Hist., vi, p. 281, Dec., 1840; Synopsis Starfishes, p. 12, 1866. Fisher, 1911*b*, p. 260.
Echinaster Perrier, Révis. Stell. du Mus., Arch. Zool. Expér., iv, p. 364, 1875. A. Agassiz, North Amer. Starfishes, p. 97, pl. x, 1877 (structure of skeleton). Viguier, Squelette Stell., Arch. Zool. Expér., vii, p. 123, pl. vii, figs. 1-7, 1878 (structure of skeleton). Sladen, Voy. Chall., Zoöl., xxx, p. 553, 1889. Perrier, Exp. Trav. et Talism., p. 146, 1894.

Disk rather small. Rays five, of moderate length, rounded. Larger dorsal and marginal ossicles strong, lobate, convex in the middle, and having a central mammilla and pit for the attachment of the usually solitary spine. The larger ossicles are united into reticulations by small, rounded, connective ossicles, leaving large papular areas; these may be intermarginal and often, also, interactinal.

The whole surface is covered in life with a rather thick, soft integument, containing small granules on the spines. Dorsal spines mostly isolated, sometimes in small groups, conical, acute.

Upper and lower marginal plates small, not very distinct, with spines like the dorsals. Adambulacral spines in a small transverse row of two to four; the inner ones are smaller, inserted in the groove, just below the margin.

The genus *Othilia* Gray, December, 1840, appears to be a synonym of *Echinaster* Müller and Troschel, April, 1840. The type of the latter was *E. spinosus* = *Asterias echinophora* Lam., both by virtual tautology and by designation. (See foot-note in Müller and Troschel, Syst. Ast., p. 22, 1842.) *Echinaster* of Gray, 1866, is *Acanthaster* of later writers. *A. echinophora* Lam. appears to be identical with *A. spinosa* Retz., 1783, the type of *Othilia*. The name *spinosus* cannot be used for any species, because it was preoccupied by *A. spinosa* Müller, 1777.

Fisher (op. cit., 1911*b*, p. 260) separated *Othilia* from *Echinaster* because it has intermarginal and sometimes, also, actinal papulæ. The type of *Echinaster* and also *E. sentus* (Say) have interactinal papulæ, as do the other American species.

Echinaster of Fisher is probably *Rhopia* Gray, but he does not give the type in his table. The type of the latter was *R. seposita* of the Mediterranean. Although that was the first species mentioned under *Echinaster* by Müller and Troschel, April, 1840, their later designation of *E. spinosus*, as the type, seems to settle the question of the type of *Echinaster*.

ECHINASTER (OTHILIA) ROBUSTUS Verrill, sp. nov.

Disk rather large. Rays five, large, stout, rather short, obtuse. Radii, 15 mm. and 42 mm.; ratio, 1 : 3.5. The disk is flattened in drying and doubtless measures more than it would in life.

The dorsal spines are large, conical, acute; nearly equal, isolated and pretty regularly spaced, the distances between being about 3 mm. to 4 mm.; height of the spines, 2 mm. to 3 mm. The papular pores are numerous and have large angular or rounded papular areas between. The dorsal and upper marginal spines form about seven rows, but they stand nearly in quincunx, so that the rows are not very distinct.

On the actinal surface there is one row of ossicles bearing spines, the inferomarginals, in contact with the adambulacrals. In this row, one, two, three, and sometimes four, stand on one plate. Sometimes

there is an additional imperfect interpolated row below the superomarginals distally. The ventral spines are rather smaller than the dorsals.

The adambulacral spines mostly form a transverse group of three on the distal plates; but proximally often one and two on alternate plates. The inner or furrow spine is much the smallest, and stands just within the margin; it is tapered, acute, and about half as long as the outer ones. The latter are stouter and acute, but smaller than the marginals. When three are present, the intermediate one is intermediate in size. The outer ones are somewhat webbed together at base.

Interactinal plates and spines are absent. The inferomarginals are united directly to the adambulacrals, the latter being transversely oblong at the surface. Two or three short, irregular rows of intermarginal ossicles are interpolated between the upper and lower marginals at the bases of the rays. The large spiniferous dorsal ossicles are thick, convex and lobulated. The smaller connective ossicles are rounded and elliptical, thick, or biscuit-shaped; and many of them have a naked, glistening, round, central area, covered with very uniform minute punctulations. Similar punctate ossicles occur on the lateral and ventral surfaces, between the spines.

The two apical oral spines, and the pair of epioral spines, are about equal and similar to the adambulacrals, but not so large. The lateral adoral spines are small and strongly divergent. A few solitary papulæ stand between the inferomarginal and adambulacral plates. Ambulacral feet and pores are large. Madreporic plate small, prominent, with few rough gyri.

The type is from Sooke, Vancouver Island (Canadian Geological Survey, 1893), received through Mr. J. F. Whiteaves.

ECHINASTER TENUISPINUS Verrill.

Plate CVII, figure 2 (type).

Echinaster tenuispinus VERRILL, Trans. Conn. Acad. Sci., I, pp. 577, 594, 1867. Ives, Proc. Acad. Nat. Sci. Philadelphia, 1889, p. 171; List of Echinod., Cabinet of Stearns, p. ii, 1891. Sladen, Voy. Chall., XXX, pp. 554, 812, 1889. ?? Clark, Proc. Boston Soc. Nat. Hist., XXIX, p. 319, 1901.

A large five-rayed species with long, tapering rays, swollen at base, but becoming slender toward the tips. Radii, 14 mm. and 91 mm.; ratio, 1 : 6. This specimen is one of the original types.

Dorsal spines unusually numerous for this genus, but mostly isolated, rather small, usually 1 mm. to 2 mm. long, slender, acute;

they are scattered over the surface, somwehat in quincunx, but in some parts seem to belong to about twelve to sixteen rows.

The dorsal ossicles are strong, deeply lobulate, and openly reticulate, leaving many papular areas, with numerous small papulæ. The madreporic plate in this specimen is double, the two parts nearly equal, rounded, and a little separated, covered with small spinules. The superomarginal plates are scarcely distinguishable from the dorsal ossicles, except distally; they mostly bear one or two conical spines. The inferomarginals are a little larger, strongly lobed, and often bear two spines not distinctly larger than the dorsals. A row of small interactinal ossicles, part of them bearing small spines, is interpolated proximally. The adambulacral spines stand in a transverse row of three, or sometimes four, on each plate, besides a small, short one (rarely two) within the margin of the groove. They are subequal, round, a little tapered, blunt, and decidedly longer than the outer spines. The one next the margin of the groove is usually, but not always, the longest; the outer one is the shortest.

This species occurs commonly from Panama to Lower California. It is said to occur also at San Diego, California.

The types were from La Paz, Gulf of California; San Diego (Ives, 1891); Bay of Pichilinque (Ives, 1889); Monterey, California (Ives, 1889). The latter is probably an error; it needs confirmation.

Mr. Clark, op. cit., 1901, mentions a specimen from Puget Sound, which he refers doubtfully to this species, as having the rays "long (52 mm. to 62 mm.) and very slender, and though rough, they are not spiny." This must be a different species or genus if it has no obvious spines.

Perhaps the locality label was erroneous, as was the case with several other species in the same collection. It was not to be found when I studied the collection, at Columbia University.

Genus **Henricia** Gray.

Henricia Gray, Ann. Mag. Nat. Hist., vi, p. 184, November, 1840; Synopsis Starfishes, p. 5, 1866. Bell, Ann. and Mag. Nat. Hist., vi, p. 473, 1890; Catal. British Echinod., p. 95, 1892. Fisher, 1911*b*, p. 266.

Rhopia (*pars*) Gray, op. cit., 1866, p. 12.

Cribella Forbes, Brit. Starfishes, p. 100, 1841, or December, 1840.

Echinaster (*pars*) Müller and Troschel, April, 1840; Syst. Aster., p. 22, 1842.

Linckia Forbes (*non* Nardo), Mem. Wern. Soc., viii, p. 120, 1839.

Cribrella FORBES, Brit. Starfishes (as *Cribella*), 1841 (*non* Agassiz). L. Agassiz (*pars*), Prod., in Mem. Soc. Sci. Nat. Neuchâtel, I, p. 191, 1835. Lütken, Grönl. Echinod., p. 30, 1857. Norman, Ann. and Mag. Nat. Hist., XV, p. 124, 1865. Verrill, Proc. Boston Soc. Nat. Hist., X, p. 345, 1866. Perrier, Révis. Stell. Mus., Arch. Zool. Expér., IV, p. 373, 1875. A. Agassiz, North Amer. Starfishes, p. 113, pl. XVIII, 1877 (structure of skeleton). Viguier, Squelette des Stell., Arch. Zool. Expér., VII, p. 126, pl. VII. figs. 8-15, 1878 (odontophore). Sladen, Voy. Chall., XXX, p. 540, 1889. Perrier, Exp. Trav. et Talism., p. 143, 1894. Ludwig, Fauna Arctica, p. 473.

Form usually neatly stellate with slender terete rays; sometimes with short rays.

Dorsal ossicles small, convex, closely united or overlapping at the edges, and arranged in a reticulated or areolated pattern, leaving small papular areas, carrying few, often single, papulæ, and not covered with a thick integument. Dorsal spines minute and nearly uniform, crowded in divergent clusters on the convex ossicles, both on the dorsal and lateral surfaces. Adambulacral spines in transverse, usually double rows, or in multiple clusters of small graded spines on the outer side of the plates; the inner spine is compressed and inserted within the margin of the groove as a furrow-spine; sometimes two are present in the grooves.[1]

Superomarginals small, often indistinct and like the dorsals. Inferomarginal plates small, but distinct, often larger than the superomarginals, contingent with the latter distally, but separated proximally by one, two, or more rows of interpolated marginal ossicles, varying in number and extent, and thus causing great variations in the thickness and taper of the rays. Peractinals and inferomarginals similar and closely joined, convex, and covered with small spinules, the rows separated by papular pores; the papulæ may occur also between the peractinals and adambulacrals.

Pedicellariæ have not been observed in any species. The eggs and young are carried under the oral region.

The madreporite is generally covered with spinules like those on the other dorsal plates.

The West Indian species, *H. antillarum* (Perrier, as *Cribrella*), has six rays and two madreporites. It appears to be autotomous.

[1] A new genus, **HENRICIDES,** is now proposed for *Henricia heteractis* Clark (op. cit., 1909, p. 530, pl. XLIX, figs. 1, 2), from Australia.

It has six or seven rays, multiple madreporites, and is probably autotomous. Dorsally it is like *Henricia.* It has no furrow-spines; the outer side of the adambulacral plates bears a marginal row or comb of five or six spines projecting over the furrow, and back of these a group of divergent spines.

This genus differs from *Echinaster* in the absence of thick external integument; in the covering of minute spinules; and in the nearly uniform small ossicles of the dorsal and lateral skeleton, the connective ossicles being almost indistinguishable from the primary series. There are no large mammillate, spiniferous ossicles, nor any intermediate naked ones, above or below. The papular areas are much smaller and the papulæ stand singly or in small groups.

In the species that I have studied there is but one well developed row of interactinal plates, sometimes as large as the inferomarginals proximally, though generally much smaller, and often bearing finer spines. This row of peractinals may extend merely to the middle of the ray, but it often disappears only close to the tip. Its ossicles are closely joined to the outer side of the adambulacrals, which they about equal in length, and consequently in number, but in some species there are intervening papulæ. In some cases a second short row of synactinals is developed proximally, in large adult specimens. The adambulacral plates are transversely oblong.

According to the accepted rules of priority it seems necessary to adopt *Henricia* instead of *Cribrella* as the name of this genus.

The generic name *Cribrella* was proposed tentatively by Agassiz (op. cit., p. 191, 1835), as a substitute for *Linckia* Nardo (Isis, 1834), evidently because the latter had been previously used in botany. Agassiz did not then actually use it as the name of the genus, but retained *Linckia*. The species that he cited were *L. variolata* N., *L. typus* N., and *L. franciscus* N. These belong to the Ophidiasteridæ, and to *Linckia* as now restricted. Therefore the generic name, *Cribrella*, if used at all, must be considered as dating only from Forbes, who published it in 1841 (or December, 1840, at the earliest), spelling it "*Cribella*," evidently by a typographical error, and applied it wrongly to the present genus.

J. E. Gray, however, as shown by Bell,[1] had published a valid name, *Henricia*, for the genus at a slightly earlier date. (Op. cit., November, 1840.)

Therefore, if the monthly part of Forbes's work, including *Cribella*, was published December 1, 1840, as Bell states, the name *Henricia* evidently has one month of priority and should be adopted. His work, as a whole, is dated 1841.

[1] Op. cit., VI, p. 473, 1890. Bell there states, on the authority of the publishers, that Forbes's "British Starfishes" was published in six monthly numbers, from October, 1840, to March, 1841.

Moreover, as used by Agassiz, 1835, it was a synonym of *Linckia,* and if the latter name be retained, it must be rejected on that account also.

In the system of Agassiz, 1835, this genus would have been included under *Stellonia* Ag.; together with *Echinaster, Solaster, Heliaster, Asterias,* etc.

This genus is remarkably well represented on the North Pacific coast. Professor Fisher (1911*b*) has described numerous species and named varieties or subspecies from the Northwest coast, as well as various additional minor varietal forms, not named.

The genus is a very difficult one and the number of forms on the Northwest coast is surprisingly great, as compared with those of the North Atlantic, where but one species is usually recognized (*H. sanguinolenta*), at least on the American side.[1]

The latter, from our coast, though variable to a considerable extent in form and spinulation, presents no such extensive variations as it and other species show on the Pacific side. I have personally examined more than ten thousand specimens of the Atlantic *sanguinolenta,* from a great variety of localities, and at least several hundreds of the allied North Pacific forms, and can speak with confidence as to the far greater variations of the latter.

To determine just how many of the North Pacific forms are really "species," or even reliable subspecies or varieties, is not possible, at present. Perhaps it never will be possible, though much nearer approaches to the solution of the problem may be made hereafter, aided by more studies of the forms in life, and by far more extensive collections.

Professor Fisher thinks, as I have long believed, that many of the puzzling forms are mere hybrids between a few associated species. If so, some of the hybrids may, by isolation, etc., have formed more or less fixed local varieties, or even real species, in modern times, while others may be, at present, mere sporadic or individual cases. Much larger collections, from wider areas, might

[1] Many years ago (op. cit., 1894), I gave a full description of *H. pectinata,* a supposed second species from New England. Later I reduced it to a variety of *H. sanguinolenta.* Yet Dr. Fisher quotes it (1911*b*, p. 10) as a "nomen nudum." The same form occurs in Bering Sea. See below, and pl. XLIX, figs. 1, 1*a*. Another form (*H. eschrichtii* Müller and Troschel) was formerly described (1842) from Greenland, but it has almost invariably been considered, and as I believe correctly, a slight variation of typical *sanguinolenta.* Dr. Fisher has applied the name to what I consider entirely different forms, from the North Pacific.

well enable us to distinguish sporadic forms from more fixed races, even among hybrid forms.

At present, we can only describe the apparently more important forms, as they occur in our collections. Where so many forms exist, it is not strange that each collection, of any great size, should give diverse results, even could the "personal equation" be eliminated.

However, there are certain leading forms in that fauna that all investigators agree upon, as well established species.

Dr. Fisher has also described and figured several very distinct species from the deeper water, that do not come within the bounds of this report, such as *H. polyacantha, H. clarki, H. aleutica, H. asthenactis.*

Aside from those, he recognizes (pp. 267, 303) eight principal species and named varieties from the shallow waters. The large collections that I have studied make it seem necessary to add to those, four or five additional forms, worthy of names.

Of the dozen or so of named forms, I believe that about five or six represent genuine species, besides the four deep-water species mentioned above. But most of the shallow-water forms from south of Puget Sound may be referred to *H. leviuscula.*

In a few cases my own determinations differ from those of Professor Fisher, especially in respect to the arctic forms; but in the main I believe he has treated the forms very judiciously. His collections from that coast were larger than mine. His descriptions are detailed and his illustrations numerous and excellent. To duplicate them would be superfluous. Therefore his work should be consulted by everyone interested in the group, and especially for the doubtful forms. The following details are, therefore, abbreviated in many cases.

It is not improbable that some of the notable variations are mere individual variations of variable species, without any constancy. Other variations may be due to seasonal changes in nutrition and rapidity of growth. I am disposed to think that the marked differences frequently noted in the roughness or thorny character of the tips of the spinules of all the species may be due to changes in the rapidity of growth. Those that have the tips of the spinules spiculose or thorny may be growing, as to their spines at least, more rapidly than those individuals with more even or rounded tips, as in those of typical *leviuscula* and var. *lunula.* Such differences of growth may be due to the abundance or scarcity of food, or to

seasonal changes in the temperature of the water, or to the partial suspension of growth during the breeding season, and the lack of nourishment in the case of the female, while incubating the eggs and young. Moreover, I have good reason to believe that in some species there may be marked sexual differences, though my material is not sufficient to determine this with certainty.

It is known that in many species the female, while carrying the eggs and young, under the mouth and oral part of the disk, arches up the abactinal side of the disk to a considerable extent, and makes a central cavity beneath, in which the eggs are held. (See Fisher's figure, pl. LXVIII, fig. 1.) In some species this seems to be only a temporary condition, disappearing at other periods. But in *H. tumida* V., of Alaska, it seems to have become a permanent condition, in an exaggerated form, for the oral region and mouth are deeply withdrawn and a number of the oral plates have become modified, to fit this condition. Whether all such individuals are females I do not know. The male may, perhaps, be quite different in form.

Variations in the slenderness of the rays seem to be of little importance in this genus, unless of great extent. The thickness of the rays at base depends partly on the number of rows and extent of rows of the interactinal and intermarginal plates, but also upon the number and size of the abactinal ossicles. These are constantly increasing in number by the interpolation of new ones, and probably by the splitting up of the older and larger ones, while at the same time the smaller ones are growing larger. Where such large numbers of ossicles exist, a slight change in the size or form of each will cause great changes in the whole skeletal structure.

That variations in growth, more or less periodically, may account for many apparent varieties, has been notably confirmed, for me, by finding certain specimens of *H. sanguinolenta,* with rays equal in size and length, but having the marginal and other ossicles and spinules as different, on some of the rays compared with others, as they usually are in different " varieties " of the species, not only in size, but also in the form and number of spinules upon them. The variations, as between adjacent rays, may be as much as fifty per cent in the size of inferomarginal plates and number of their spinules. These are not cases of restorations after injury, which often also, cause peculiar abnormal variations.

The habit of carrying the eggs and young till well developed, as in *Leptasterias* and *Solaster,* is conducive to variations perpetuated by isolation of colonies, due to their slow rates of diffusion. The

remarks on this subject under *Leptasterias* will no doubt apply just as well to *Henricia,* for the young are carried in the same way. (See pp. 116, 117, above.)

Consequently, it is not at all surprising that numerous more or less localized varieties of *Henricia* should be found on the vast extent of coast-line from Puget Sound to the Arctic Ocean. The wonder rather is that any of the species or varieties should preserve their essential characters, as several of them do, over such extensive regions as the whole coast-line from Vancouver Island to the Aleutian Islands, for example, or even from California to Unalaska.

HENRICIA LEVIUSCULA (Stimpson) Fisher.

Plate XII, figures 5, 6; plate XIII, figures 1, 2; plate LXXXVIII, figures 1, 1*a*, 2-2*c* (varieties).

Linckia leviuscula STIMPSON, Journ. Boston Soc. Nat. Hist., VI, p. 529 [p. 89], 1857.

Cribrella leviuscula VERRILL, Trans. Conn. Acad., I, p. 326, 1867. Sladen, Voy. Challenger, XXX, pp. 542, 806 (distribution only). Ives, Proc. Acad. Nat. Sci. Philadelphia, 1889, p. 169 (distribution only). De Loriol, Mém. Soc. Phys. Nat. Genève, XXXII, No. 9, p. 14, pl. II, figs. 2-2*c*, 1897 (description only). Clark, Proc. Boston Soc. Nat. Hist., XXIX, p. 327, 1901 (varieties).

Henricia leviuscula FISHER, 1910, p. 570; 1911*b*, p. 280, pl. LXIX, figs. 1, 2; pl. LXX, figs. 1, 2; pl. LXXI, figs. 2, 3; pl. CXI, fig. 6.

Rays five, long and terete, gradually tapered. Disk rather small. Radii of an average dry specimen, 8 mm. and 42 mm.; ratio, about 1 : 5.25. Breadth of ray at base, 9 mm. A larger specimen has the radii 12 mm. and 75 mm.; ratio, 1 : 6.25. It grows much larger than this. One example from Alaska has the radii 15 mm. and 85 mm. Many specimens have more slender rays, others have them stouter than those given.

The dorsal ossicles are thick and pretty closely united in a fine-meshed reticulation, leaving very small papular spaces between them; the papulæ are mostly isolated in small specimens, but three to five together in large ones. The ossicles are convex, unequal, rounded, elliptical, curved lunate, or short cordate. The convex spinulose surface is often crescent-shaped. The clusters of spinules are usually densely crowded, varying much in size and form, as do the ossicles; but the greater number in the typical variety are rounded, or short elliptical, with the longer axis transverse to the rays or often oblique.

The spinules are very small, short, nearly even, usually with minutely spinulose tips. The two marginal and the peractinal rows

of ossicles and spines are very distinct and regular, running parallel nearly to the base of the rays; but the peractinals are rather smaller and slightly more numerous, so that not all are opposite the marginals. The ossicles of the two marginal rows are opposite, the inferior ones a little larger and more rectangular. The spiniferous surface is broadly elliptical or squarish, bearing dense, broad elliptical or quadrilateral clusters of spinules, slightly larger than the dorsals, and not much longer transversely than longitudinally. The clusters of spinules on the peractinal ossicles are rather smaller and more rounded, but distinct nearly to the tips of the rays, where they become very small. The upper and lower marginal rows diverge rather abruptly, close to the bases of the rays, and two or three very short rows of smaller ossicles are interpolated, making a small, sharply rhombic, interradial area. The madreporite is spinulose.

The adambulacral ossicles bear a double or triple transverse group of about twelve to twenty, or even more, unequal spines, increasing in size and length from the exterior to the margins of the groove. The outer ones are very small, not larger than the peractinals; the odd one on the margin of the groove is larger than any of the others; within the groove there is a small and very short spine.

The adoral and oral spines are small, and not unlike the other adambulacrals, but the perorals and epiorals are usually a trifle stouter than the rest. (See pl. XIII, fig. 2.)

In life the color is usually orange or orange-red, but varies to a variety of other colors, including dark red and purple. It is often mottled with red or brown on a ground-color of yellow, orange, drab, light brown, pink, or lavender.

This species is common in shallow water and at low tide, from Monterey, California, to Yakutat, Alaska.

I have examined specimens from San Luis Obispo Bay; Monterey; San Francisco; Tomales Bay; Victoria, Vancouver Island; Queen Charlotte Islands; Sitka; and many other places. It was taken by the Harriman Expedition at Sitka, Yakutat, Kadiak, Orca, etc. Formerly recorded from Puget Sound (Stimpson, Clark, etc.); Marmot Island (Ives, 1889); Vancouver Island (De Loriol); California, etc. Mr. Fisher (1911*b*) gives its range as from the Aleutian Islands to San Diego, California, and from low tide to eighty fathoms, but most of his localities are south of Sitka, and in less than fifty fathoms.

VARIATIONS.

This species varies considerably in the proportions of the rays and disk, some specimens having very long and slender rays, with a small disk, while others have the rays shorter and more robust,[1] much as in *H. sanguinolenta.* There is, also, considerable variation in size and form of the dorsal ossicles, some of the specimens almost lacking the peculiar curved forms, characteristic of most. The dorsal spinules, always numerous, vary in size, so that the degree to which they are crowded is variable. Commonly they are obtuse, or clavate, but often they are acute, or have thorny or spiculose tips. The number and size of the adambulacral spines are also variable. But the species is usually easily recognized.

Six-rayed specimens occur rarely on the California coast.

Professor Fisher (op. cit., 1911*b*, p. 283) mentions a dwarf littoral variety found at Monterey, California, which carried clusters of orange-colored eggs in January. The disk was arched, making the oral region concave, as usual in this genus when eggs or young are carried by the mother.

The following eight varieties, from California to Sitka, are not regarded as subspecies by me, but rather as local varieties.

HENRICIA LEVIUSCULA, Var. LEVIUSCULA (Stimpson).

Plate XII, figure 5; plate XIII, figures 1, 2.

The specimen in the U. S. National Museum, supposed to be Stimpson's type, is a small, slender-rayed specimen in rather poor preservation.

It belongs to the common variety having rather large, well-rounded dorsal pseudopaxillæ, pretty close together, and with small papular areas. The paxillary spinules are very short, even, and numerous.

The two rows of marginals and the interactinal row of plates are very distinct and pretty regular.

The inferomarginals are the larger and are squarish. The adambulacral spines are rather numerous; the inner two to four are the larger.

[1] Prof. H. L. Clark (op. cit., p. 327, 1901) proposed varietal names based only on the relative length of the rays and size of the disk. The stouter- and shorter-rayed form (radii about 1:2-3.5) he called var. *crassa;* the longer-rayed form (radii about 1:5-6), var. *attenuata.* But as all grades of intermediate forms occur, these variations cannot be regarded as of much significance. Several other species of the genus, if not all, vary in the same manner.

I have seen many specimens that agree well with Stimpson's typical form. They are peculiar mainly in having the larger dorsal ossicles, round or elliptical, and covered with compact clusters of stout clavate or obtuse spinelets, so crowded together as to give the groups an evenly convex form. They are peculiar, also, in having fewer and larger adambulacral spines than in some other varieties. These stand in two transverse rows of about six to eight each, increasing from the outer to the furrow end of the plate, but even the outer ones are as large as the adjacent peractinal spines, while the marginal odd spine is relatively large and stout; the single spine within the groove is small and slender.

Monterey, San Francisco, and other localities on the coast of California and northward to British Columbia. The three figures are all from one specimen, from Monterey.

This seems to be a southern variety of the species. The increased thickness of the ossicles and spines may be due to the warmer climate, or to a larger amount of lime in the food.

HENRICIA LEVIUSCULA, Var. LUNULA Verrill, nov.

Plate LXXXVIII, figures 2-2*c* (details).

This is one of the most common shore starfishes from California to middle Alaska.

Rays five, variable in length and thickness, usually terete and regularly tapered.

The marginal, interactinal, and adambulacral plates and spinules are essentially as in the typical *leviuscula;* and as in that form the marginals and interactinals form three very evident, regular, longitudinal rows of imbricated plates that are larger and wider than the rest, and covered with large numbers of spinules.

The only notable feature for distinction is found in the forms of the principal abactinal pseudopaxillæ and ossicles. These, instead of being nearly round or broad elliptical, as in typical *leviuscula,* are curved in a more or less crescent form with blunt cusps, or may be said to have an elongated reniform shape, partially surrounding and enclosing the papular pore on the concave side, which is adoral.

Although this peculiarity appears to be of minor importance, it gives a special facies to the variety, easily recognized even by a superficial examination.

Large numbers of this form have been examined, from Vancouver Island, Queen Charlotte Islands, California, etc., and some from Sitka and Dutch Harbor. The specimen affording the figures of the ossicles was from Monterey, California.

This variety often intergrades with the typical form and with other varieties. It is, perhaps, the predominant form of the species, in shallow water, when well grown, but the original form, described by Dr. Stimpson, had roundish abactinal ossicles.

In many cases the longer, lunulate ossicles show one or more lines or grooves across them, apparently indicating a process of dividing into two or more shorter parts. Should such a process occur extensively, it would convert an individual of this variety into the typical form. This may, perhaps, occur periodically, or at the times of more rapid growth.

HENRICIA LEVIUSCULA, Var. ATTENUATA (Clark).

Cribrella leviuscula, var. *attenuata* H. L. Clark, Proc. Boston, Soc. Nat. Hist., xxix, p. 327, 1901.

Some specimens from Departure Bay, British Columbia, are remarkable for the slenderness of the rays. The most attenuated has the radii 7 mm. and 50 mm.; ratio, 1:7. In another they are 9 mm. and 54 mm.; ratio, 1:6. In the former the breadth of the ray in the middle is 5 mm.; in the latter it is 6 mm. These are, therefore, much more attenuated than the one named by Dr. Clark.

The rays are terete and evenly tapered from close to the base. The dorsal pseudopaxillæ are roundish, pretty uniform in size, even, and crowdedly covered with minute spinules.

The two marginal rows of plates are very evident, their plates are squarish, about equal in size to dorsal ones, and covered with similar spinules. One row of actinal plates, similar in size proximally, extends to the distal fourth of the ray; their spinules are a little longer and coarser. Adambulacral spines are slender, ten to twelve to a plate; the inner ones are larger.

The color is orange and orange-red above; yellow below.

Departure Bay, British Columbia (C. H. Young, Geological Survey of Canada); Puget Sound (Clark); etc.

HENRICIA LEVIUSCULA, var. INEQUALIS Verrill, nov.

Plate lxxxviii, figures 1, 1*a*.

The type is rather large, with five long, regularly tapered, moderately slender rays. The radii are 15 mm. and 83 mm.; ratio, 1:5.5.

The dorsal surface is closely covered with small parapaxillæ, mostly roundish or elliptical, sometimes slightly curved, and bearing numerous small, divergent, often stellate, very slender, partly clavate,

rough-tipped spinules, much like those of var. *dyscrita*. The papular pores are numerous and rather small; the areas are mostly narrower than the plates.

The two rows of marginal plates and the peractinal row, on the proximal part of the ray, are regular and subequal, transversely elongated, much like those of var. *leviuscula* in form and size; close to the base of the ray there may be a few small subactinal plates, and two short rows of intermarginals. All these plates are covered with slender, rough-tipped, divergent spinules like those of the dorsal side, but longer; there may be fifty or sixty on the larger marginal plates, of which about twenty-five are on the border.

The adambulacral spines are the most characteristic feature. They are all much larger and longer than in the typical variety, mostly terete, slightly clavate, obtuse. There are mostly but ten to twelve, paired in two rather regular, divergent rows, the inner one or two only a little larger. The rest are graded, but the outermost are more than twice as large as those of the marginals.

The type is from the Queen Charlotte Islands (coll. G. M. Dawson, Geological Survey of Canada), received in exchange from J. F. Whiteaves (No. 5133, Yale Mus.). Others, very similar, are from off Victoria and Sitka.

HENRICIA LEVIUSCULA SPICULIFERA (Clark).

Plate LXXXVII, figures 2-2*b*; plate CVII, figure 3.

Cribrella spiculifera CLARK, Proc. Boston Soc. Nat. Hist., XXIX, p. 328, pl. II, figs. 1, 2; pl. IV, fig. 1, 1901.

Henricia leviuscula multispina (*pars*) FISHER, op. cit., 1910, p. 571; 1911*b*, p. 286, pls. LXXII, LXXIII.

Henricia spiculifera FISHER, op. cit., 1911*b*, p. 295 (copied from Clark).

The two type-specimens of this subspecies or variety, which were in the collections of Columbia University, have been examined by the writer. They were preserved in alcohol. Radii, in one example, about 14 mm. and 64 mm.; in the other, 15 mm. and 77 mm. Ratios, about as 1 : 5. The five rays are rather stout and swollen at base, tapered distally to rather slender tips.

In these specimens, which were somewhat relaxed or flaccid in alcohol, the dorsal ossicles are not closely crowded, but seemed separated by intervening spaces, the visible portion being prominent. The papular areas appear rather large. The dorsal ossicles are small, and very unequal in size and form and show no definite arrangement in radial rows. Many of the larger ones are prominently crescent-shaped, as exposed; others are oblong or elliptical;

the smaller ones are rounded or elliptical. All are crowdedly covered with very numerous fine and slender, rather long, spicule-like, equal spinules.

The upper and lower rows of marginal plates are easily recognizable, the lower ones larger. They are distinctly larger than the adjacent dorsals, but bear the same kind of slender spinules. They are transversely oblong-elliptical in form, becoming more quadrangular distally, where the two rows are contiguous and similar. Proximally they diverge strongly and are separated at the base of the rays by two or more short rows of intermarginal plates, similar in form to the supramarginals, but rather smaller; of these, the middle row may extend to about the mid-length of the ray.

A single row of smaller interactinal parapaxillæ (sometimes double) intervenes between the lower marginals and adambulacrals. They are somewhat quadrangular or roundish in form and extend nearly to the tips of the rays; they bear fine spinules, like those of the marginals. The papulæ between the marginal and peractinal plates are rather large and mostly stand isolated.

The adambulacral plates bear an unusually large number of spinules, often twenty-five to thirty or more. These spinules are slender, erect, and closely crowded, decreasing in size and length from the margin of the groove outwardly; the outer ones are similar in size to those of the adjacent interactinal plates. They mostly stand in three or four radial rows on each plate, while there may be six to nine in each transverse row. The two or three standing at the margin of the groove are distinctly larger than the rest; and next to these is a second oblique row, usually of three, that are smaller, but distinctly larger than the third row. The single furrow-spine is short, acute, and hardly reaches the margin. The adambulacral spines are all slender and not clavate.

Adoral and epioral spines numerous, crowded, scarcely larger than adjacent adambulacrals, and similar in form, seven to nine in each marginal series.

The general appearance of this variety is similar to that of a stout-rayed *H. leviuscula* or *sanguinolenta,* but it is peculiar in having unusually large numbers of crowded and slender adambulacral spines on each plate.[1] A larger series of specimens shows apparently intermediate forms between this and *leviuscula.*

[1] Dr. Clark's diagrammatic figure (pl. IV, fig. 1) represents them as much more regular and equal than they actually are. The exterior ones are represented as about as long as the inner or marginal ones, but they are not half as long.

After a careful study of the type I cannot see any good reasons for considering *spiculifera* a real species, distinct from *leviuscula*. Some of the differences are due to the somewhat flaccid condition of the alcoholic specimens. Intermediate specimens are of frequent occurrence in the same region.

Puget Sound (Expedition of Columbia University, 1896-7).

Other good examples are from Kadiak, 5 fathoms, and Sitka (W. R. Coe, Harriman Expedition).

A specimen similar to the above, in many respects, has been sent to me by the U. S. National Museum. It was taken at Bering Island by Mr. N. Grebnitsky. It is the specimen figured (pl. CVII, fig. 3; and pl. LXXXVII, figs. 2, 2*a*).

I believe that many of the intermediates are the same as *spiculifera*, which has a decided resemblance to *leviuscula* dorsally. The more arctic specimens may have had a different origin, and belong with a different species, more nearly related to *sanguinolenta*. The four specimens figured by Fisher are all from the Aleutian Islands and Kadiak, within the known range of *leviuscula*.

I should refer most of his figured specimens to *spiculifera*, judging from the description and figures, which are very good. Perhaps it is merely the normal cold water form of *leviuscula*.

HENRICIA LEVIUSCULA, Var. MULTISPINA Fisher.

Henricia multispina FISHER, op. cit., 1910, p. 571; 1911*b*, p. 286 (*pars*); pls. LXXII and LXXIII (*pars*).

H. multispina Fisher, as figured, differs but slightly, and perhaps ought to be called the same as *spiculifera*. Some of the differences given by Fisher, on his p. 297, do not hold good, being partly due to the different states of preservation. This applies particularly to the dorsal skeleton. The arrangement of the adambulacral spines is essentially the same, but Clark's diagrammatic figure is misleading. Such differences as actually exist seem trivial and such as are notoriously variable.

The particular point which makes the full identity doubtful is the fact that some of Dr. Fisher's specimens of *multispina* came from Bering Sea and Siberia, far north of the ordinary range of *leviuscula*. The type was from the Aleutian Islands. Fisher himself states, on pp. 288, 289, that large numbers of his specimens from the shore and very shallow water, south of the Aleutian Islands, at Bristol Bay, Kadiak, etc., are intermediate between the type and *leviuscula*. However, Dr. Fisher himself records *leviuscula* from Bering Sea.

I have seen no specimens of it from much north of the Aleutian Islands, which are usually considered its northern limit.

I have studied specimens from Bering Sea, which are, perhaps, of the same variety as some of those recorded by Fisher from the same region. My arctic form, however, appears to be a variety of *H. sanguinolenta,* which is much like the Atlantic variety *pectinata.*

Professor Fisher gives the range of his *multispina* as from Oregon to Bering Strait and Kuril Islands, and from low tide to 238 fathoms.

This species or subspecies appears to be closely related to, and may be the same as *Henricia densispina* (Sladen, 1878, p. 432, pl. VIII, figs. 5-9, as *Cribrella*), from the Straits of Korea, 40 fathoms.

The latter also has two spines on the furrow margin and several graded pairs back of them, with very numerous, crowded, rough, thorny spinules on the close marginal and dorsal plates; papular areas small, mostly with isolated or few papulæ.

The Japanese species, figured, but not described, by Ives (op. cit., 1891, p. 212, pl. IX, figs. 1-4) as *Cribrella sanguinolenta,* is not that species. It belongs to the section of the genus having a pair of spines on the furrow margin, but it has fewer on the actinal surface. Its dorsal ossicles are narrow, very openly reticulated, bearing spinules in about two rows, and surrounding unusually wide papular areas. It may be called *HENRICIA JAPONICA.*

HENRICIA LEVIUSCULA, var. DYSCRITA Fisher (as a subspecies).

Plate XII, figure 6.

Henricia leviuscula dyscrita FISHER, op. cit., 1911*b*, p. 289, pl. LXXIV, figs. 1-5.

Form and general appearance intermediate between *leviuscula* and *multispina;* abactinal ossicles smaller than in the latter, with similar, but fewer, delicate spinules and usually larger papular areas, larger than the pseudopaxillæ. The abactinal spinules end in several delicate points.

Adambulacral plates carry about fifteen spinules; two intra-furrow spinules occur, if at all, only near the tip of the ray.

Dr. Fisher records this form from eighteen localities in 21 to 80 fathoms, from Monterey to Southern California. South of Monterey "it predominates everywhere over *leviuscula.*"

Two specimens from Sitka (coll. Harriman Expedition) seem to agree closely with this form in all respects. (See pl. XII, fig. 6.) Others are from British Columbia.

HENRICIA LEVIUSCULA, Var. ANNECTENS Fisher.

Henricia leviuscula annectens FISHER, 1910, p. 572; 1911*b*, p. 291, pl. LXX, fig. 2*d*; pl. LXXI, figs. 1-3.

Intermediate between *leviuscula* and *aspera,* but superficially more like the latter. Abactinal skeleton less open than in the latter, with smaller, deep, papular areas. Ridges between papulæ divided into distinct pseudopaxillæ, the larger with five to twenty short, stubby spinules. Marginal plates more compressed than in *leviuscula,* with comparatively few spinules. No intermarginals beyond first two or three marginals. Interactinals extend to one-half or two-thirds the length of the ray. Adambulacral plates bear ten to twelve spinules in two transverse rows and one furrow-spine deep in the groove, except near the tip of the ray, where there are two.

Dr. Fisher records this form from thirteen localities in 21 to 73 fathoms, from Washington and Oregon to Santa Barbara, California.

Specimens agreeing very closely with it were in my collections from California. The above diagnosis is condensed from that of Dr. Fisher.

HENRICIA LEVIUSCULA, Var. SPATULIFERA Verrill.

Plate V, figure 1; plate XIV; text-figure 12 (details).

Henricia spatulifera VERRILL, Amer. Naturalist, XLIII, pp. 554, 555, fig. 6, 1909.

The type of this peculiar variety is similar to an average well-grown robust specimen of *leviuscula,* var. *lunula,* in size and form, Radii, 13 mm. and 78 mm.; ratio, 1:6.

The chief peculiarity is in the armature of the adambulacral plates. These bear a crowded group of about eight to twelve spinules, in two close rows, which are remarkably large and flat, expanding distally to broad truncate tips, which are often gouge-shaped or grooved on one side. They are so large and crowded that they overlap each other and the adjacent plates, making it difficult to count their number.

The adoral and oral plates have the same sort of armature. This kind of spinules extends to the tips of the rays, the size gradually diminishing to minute spatulate forms near the tips, with the exception of a limited section in the middle of one ray, where the large, flat spinules cease abruptly and the following twenty-five pairs of adambulacral plates all bear very small, short, slender spinules in a crowded group of about fifty or more, in about four

rows, twelve to fourteen each, all of nearly the same size. They form clusters, as numerous or more so, and of as small size, as those in var. *spiculifera* or *multispina,* and more uniform in size. After these twenty-five pairs of plates, those more distal suddenly resume the same spatulate form and arrangement as on the other rays.

Probably these peculiar twenty-five plates had been injured, losing their spinules, and replacing them with the minute kind, just as some starfishes will often replace a lost spine of large size, by a cluster of granules.

The fact that a large number of uniform small, slender spinules may replace a group of few large spatulate ones, on the same ray, is, however, an important fact, showing that the character of the adambulacral spinules is not a matter of vital importance, and that it might easily vary more than it usually does, even in this variable genus.

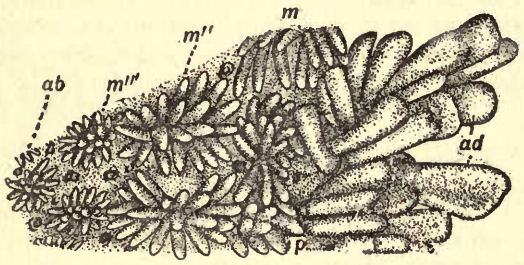

FIG. 12.

Henricia leviuscula, var. *spatulifera* Verrill, type. Portion of under side; *ad*, adambulacral spines; *p*, peractinals; *m*, *m''*, inferomarginals; *m'''*, superomarginals; *ab*, medio-lateral pines.

The dorsal skeleton is composed largely of elliptical and somewhat lunulate thickened ossicles, rather loosely arranged, leaving large papular pores, so that the surface appears rougher than in the more typical varieties. The dorsal spinules are small, mostly clavate, with thorny ends, much as in var. *multispina.*

The rows of marginal and peractinal plates are not so regular nor so conspicuous as in most varieties. The inferomarginals are the largest, but not so large as usual. The peractinals are much smaller and roundish.

The superomarginals are small, but larger than the dorso-lateral ones, and similar to the inferomarginals in form. There are two rows of intermarginals proximally, one being quite short. The spinules on all these plates are numerous and very small, much as on the dorsal side.

Papular pores exist between all these rows, and proximally, also, between the peractinal and adambulacral rows.

The type is from Monterey, California (coll. Robert E. C. Stearns, No. 2238, Yale University Museum). I have examined other specimens from Sitka, Alaska (Harriman Expedition).

Dr. Fisher records a specimen from off Santa Cruz Island, California, in 30 to 41 fathoms (sta. 4431), and two specimens from Monterey Bay shore, that may be identical with this variety. He puts them under " variety E " as " freaks."

HENRICIA SANGUINOLENTA (Müller) Bell.

Plate XLIX, figures 1, 1*a* (var. *pectinata*), and figure 2; plate LXXXVIII, figures 3, 3*a*, 4, 4*a* (varieties).

Asterias sanguinolenta and *A. pertusa* MÜLLER, Zool. Dan. Prod., 2836 and 2839, pp. 234, 235, 1776.

Asterias oculata PENNANT, Brit. Zoöl., IV, p. 61, pl. XXX, fig. 56, 1777.

Asterias spongiosa FABRICIUS, Fauna Groenl., p. 368, 1780. Gmelin, p. 3161, 1788. Desor, Proc. Boston Soc. Nat. Hist., III, p. 67, 1848.

Cribella rosea and *C. oculata* STIMPSON, Proc. Boston Soc. Nat. Hist., IV, p. 98, 1851.

Linkia oculata FORBES, Mem. Wern. Soc., VIII, p. 120, pl. III, fig. 5, 1839. Stimpson, Invert. of Grand Manan, p. 14, 1853.

Henricia oculata GRAY, Ann. and Mag. Nat. Hist., VI, p. 184, November, 1840; Synopsis, p. 5, 1866.

Linkia pertusa STIMPSON, op. cit., p. 14, 1853.

Cribella oculata FORBES, British Starfishes, p. 100 (figure), 1841.

Cribrella oculata PERRIER, Stellérides, in Arch. Zool. Expér., IV, p. 373, 1875. Viguier, Arch. Zool. Expér., VII, p. 128, pl. VII, figs. 8-15, 1878. Ludwig, Echinod. Mittelm., Mittheil., Zool. Station Neapel, I, p. 545, 1879. Duncan and Sladen, op. cit., p. 32, pl. II, figs. 18-21, 1881. Ludwig, Zool. Jahrb., p. 289, 1886. Danielssen and Koren, op. cit., p. 34, 1884. Sladen, op. cit., p. 542, 1889.

Echinaster oculatus MÜLLER and TROSCHEL, Syst. Asterid., pp. 24, 127, 1842. Düben and Koren, Kongl. Vetensk. Akad. Handlingar, p. 241, 1844.

Echinaster sarsii MÜLLER and TROSCHEL, Wiegmann's Arch. Nat., X, p. 179, 1844.

Echinaster eschrichtii MÜLLER and TROSCHEL, op. cit., 1842, p. 25.

Echinaster sanguinolentus M. SARS, Wiegmann's Arch. Nat., X, p. 169, 1844 (development). Fauna Litt. Norveg., I, p. 47, pl. VIII, figs. 3-6, 1846; Oversigt af Norges Echinodermer, p. 84, 1861.

Cribrella sanguinolenta LÜTKEN, Grönl. Echinod., p. 31, 1857. Verrill, Proc. Boston Soc. Nat. Hist., X, p. 345, 1866. Dujardin and Hupé, Hist. Nat. Zooph. Echinodermes, p. 349, 1862. Norman, Ann. and Mag. Nat. Hist., Ser. 3, XV, p. 24, 1865. Verrill, Report Invert. Anim. of Vineyard Sd., etc., in 1st Annual Rep. U. S. Fish Com., pp. 407, 420, 447, 496, 719, 1873 (auth. ed., pp. 113, 425, etc., 1874). A. Agassiz, N. Amer. Starfishes, p. 113,

pl. XVIII, 1877. Bush, Proc. U. S. Nat. Mus., p. 246, 1883. Murdoch, Report Intern. Boundary Exped., p. 159, 1885. Ganong, Echinod. New. Brunswick, Bull. Nat. Hist. Soc. New Bruns., VIII, p. 35, pl I, fig. 9, 1888. Pfeffer, Jahr. Hamb. Wiss. Ans., 1889, pp. 69, 88, 95, 1890. Fewkes, Proc. Essex Inst., p. 62, 1891. ? Ives, Proc. Acad. Nat. Sci. Philadelphia, p. 212, pl. IX, figs. 1-4, 1891 (Japan). Verrill, Amer. Journ. Sci., XLIX, p. 205, 1895 (distribution). Ludwig, Fauna Arctica, I, p. 472, 1900 (synonymy, etc.). Brunchorst, Bergens Mus. Aarbog, I, p. 28, 1902. Masterman, Trans. Royal Society of Edinburgh, XI, pp. 373-418, pls. I-V, 1902 (Abstract in Nature, LXV, p. 551) (development). Mortensen, Echinod. from E. Greenland, p. 72, pl. II, figs. 7-9, 1903 (varieties). Clark, Echinoderms of Woods Hole Region, op. cit., 1904, p. 555, pl. III, figs. 10, 11; pl. IV, fig. 22.

Echinaster scrobiculata DANIELSSEN and KOREN, Norske Nordhavsexped., Nyt. Mag. Naturvidsk., XXVIII, p. 3, pls. I, II, 1883 (young); Norwegian North Atlantic Expedition, Zoöl., Asteroidea, p. 40, pl. VI, figs. 10, 11; pl. VII, figs. 12-14, 1884. Ludwig, Fauna Arctica, I, 476, 1900 (young).

Henricia sanguinolenta BELL, Catal. Echinod., p. 95, 1892. Grieg, Bergens Mus. Aarbog, pp. 8, 12, 1896. Scott, Proc. Royal Phil. Soc. Edinburgh, p. 189, 1897. Fisher, 1911*b*, p. 271, pl. LXV, figs. 1, 2; pl. LXVI, figs. 1-5; pl. LXVIII, fig. 3. Coe, Echinoderms of Connecticut, p. 65, pl. I, figs. 1-3; pl XI, figs. 1-4, 1912.

Disk of moderate size or small. Rays five, evenly rounded in life, rather long and slender, varying to stouter forms of moderate length, usually evenly tapered to rather slender tips.

The radii of a well grown typical New England specimen of average proportions, are 14 mm. and 62 mm.; ratio, about 1 : 4.5; in another, 13 mm. and 58 mm.; ratio, about 1 : 4.5. Many have shorter rays. Ambulacral grooves are narrow and deep, often nearly closed up, so that their marginal spines interlock.

The dorsal and lateral skeleton is composed of a great number of small, nearly equal, mostly rounded and elliptical ossicles, united endwise into a fine-meshed reticulated skeleton, showing no median row of larger ossicles.

All the ossicles are covered with divergent clusters of small, slender, rough-tipped spinules, nearly uniform over the dorsal surface and sides of the rays, and on the disk. The papular areas, in the meshes, are small and usually bear but one to three papulæ.

The madreporic plate is small, with only a few rough gyri, and sometimes spinulose. The pseudo-anal pore is usually very distinct and guarded by small incurved spinules.

The superomarginal and inferomarginal ossicles are similar in size, and form two distinct rows low down toward the ventral side of the rays. Distally they are near together and parallel, closely united, leaving only a simple row of papular pores between them;

but on the proximal part of the rays they gradually diverge and two or three short rows of intermarginal ossicles are interpolated in the interradial angles.

The marginal plates in both rows are a little convex and lobate. The outer surface is oblong-elliptical, or squarish with rounded corners, united by apophyses. Their transverse diameter is often but little greater than the longitudinal one, distally, but they become more transversely elongated proximally. Their clusters of spines do not much exceed those of the dorsal and lateral ossicles, and therefore they are not so conspicuous as in *H. leviuscula* and some other species. It often requires close examination to distinguish them from the adjacent clusters, but in other cases they are larger and more regular, and quite noticeable.

The peractinal ossicles form a regular row of small, rounded plates, one standing opposite each adambulacral and closely united to it and to the opposite inferomarginal. This row often disappears at about the middle of the ray, but may extend farther, sometimes nearly to the tip. The plates bear divergent clusters of spinules, usually smaller than those on the adjacent plates, but otherwise similar.

The adambulacral plates mostly bear two transverse divergent series of small, unequal spines, usually standing in three or four or more pairs on the external surface of the plate, and regularly decreasing in size from the inner toward the external ones. The inner or ambulacral end of the plate bears two, rarely three, unpaired spines in a median row. The inner one, or furrow-spine, is attached deep within the furrow and usually projects horizontally. It is very slender and acute. The outer one is much larger and about twice as long, scarcely tapered, often compressed, blunt at the tip, and sometimes bifid. It is rather larger than the two spines of the next adjacent pair. In some large specimens many of the larger adambulacral spines are slightly capitate or clavate. Distally they often stand nearly all in one median row on each plate, but this does not often occur on the proximal plates.

Color, in life, variable, most frequently bright orange-yellow or orange-red, sometimes pale lemon-yellow, not rarely purple.

Mr. E. Desor (op. cit., III, 1848, p. 11) not only states that this species has the habit of carrying the eggs, but adds that: "On removing the eggs from the mother's embrace, she was seen to move at once directly towards and clasp them again."

The structure of the skeleton of this species has been beautifully illustrated by Mr. A. Agassiz (N. Amer. Starfishes, pl. XVIII[1]), and in some particulars by Viguier (1878, pl. VII).

The distribution of *H. sanguinolenta* is circumpolar. It is known from Greenland and the Arctic Ocean generally; on the coasts of northern Europe to Great Britain, Ireland, France, Biscay Bay, Spitzbergen, Iceland, White Sea, Barents Sea, Kara Sea, Okhotsk Sea, etc.; also off the Azores. On the northeastern American coast it is very common from Labrador to Long Island Sound, in shallow water (0 to 60 fathoms). Common in the cold area south of Martha's Vineyard, in 10 to 60 fathoms. It is also found off Cape Hatteras and North Carolina in similar depths. Taken at more than four hundred stations between N. lat. 47° 29′ and 35° 38′, by the U. S. Fish Commission. It occurs sparingly in the eastern part of Long Island Sound, at Fisher's Island, Gardiner's Island, and westward to Outer Island, near New Haven. Bathymetrical normal range is 0 to 500 fathoms. In the Bay of Fundy and on the coast of Maine it is common between tides. Off New Jersey, in 1350 fathoms (teste Sladen). Rare below 300 fathoms off the Atlantic coast. Faroe Channel, 125 to 555 fathoms (Sladen).

On the northwest coast of America the typical form and varieties have been recorded from several localities in Bering Sea and Bering Strait and in the adjacent parts of the Arctic Ocean, as well as from farther south. It is probable, however, that many of the more southern shallow-water records refer to one of the other species, or to varieties of *H. leviuscula.* I have not seen it in the collections from southeastern Alaska, and farther south, in shallow water.

I have examined Pacific specimens from the following places: Off Point Franklin, ten miles, in 13.5 fathoms, sand, 1883 (Murdoch, U. S. Nat. Mus., No. 76231, variety, very large, dry); Popoff Strait (W. H. Dall, 1872, one dry, var. *pectinata,* No. 561 (924), U. S. Nat. Mus.); Bering Island (N. Grebnitsky, November, 1889, U. S. Nat. Mus.).

Dr. Fisher (1911*b*) records it from thirty-seven stations in 30 to 344 fathoms, from Bering Sea to the Kuril Islands; and on the American side south to Washington (67 fathoms, one specimen). Nearly all of his localities are in the vicinity of the Aleutian Islands or farther north.

Mr. Ives recorded it from Japan, but his figures appear to represent a distinct species. It differs in its much looser dorsal reticulations

[1] The marginal ossicles in his figs. 1 and 4 are represented as more regular and symmetrical than they usually are in nature.

and smaller ossicles, which bear small groups of four to seven short, blunt spinules; in the smaller size of the inferomarginal plates, and their longer and larger spinules; and especially in the fewer and unusually large adambulacral spines, with a pair of stout spines standing on the margin of the groove, on each plate.

TERATOLOGY.

On the New England coast I have collected several specimens with six regular rays. One of these, from off Salem, Massachusetts, in shallow water, has the rays uncommonly slender and a very small disk. Radii, 7 mm. and 31 mm.; ratio, about 1:4.5. The dorsal pseudopaxillæ are very small and bear mostly only two to four spinules which are slender, thorny and acute; many have only a single spinule. The ossicles are small, slender, and form a fine-meshed network.

The adambulacral spines are elongated and slender, acute, about four or five in a nearly simple row.

The marginals of both rows are small and scarcely different from the adjacent laterals and peractinals, but they form pretty regular rows.

Another specimen (Yale Mus., No. 5380), from Eastport, Maine (coll. A. E. Verrill, 1870), is larger and of about the usual proportions; radii, 13 mm. and 58 mm.; ratio, about 1:4.5. The spinulation is much finer than that of the typical form. The dorsal ossicles are much smaller, and roundish, with small papular areas, approaching those of var. *miliaris*.

A specimen of moderate size, from Alaska, has two madreporic plates, near together, both interradial; one is more coarsely spinulated; they are about equal in size. This specimen is rather more coarsely spinulated than usual, dorsally, and the adambulacral spines are larger, finer, and less unequal than usual. Both rows of marginal spines are unusually small, not larger than the dorso-lateral ones, and scarcely distinguishable; they have few spinules.

HENRICIA SANGUINOLENTA, Var. PECTINATA Verrill.

Plate XLIX, figures 1, 1*a* (type).

Cribrella pectinata VERRILL, Proc. U. S. Nat. Mus., XVII, p. 278, 1894.
Henricia sanguinolenta variety C, FISHER, op. cit., 1911*b*, p. 272, pl. LXV, fig. 2; pl. LXVI, figs. 1, 3, 4, 5.

Rays five, elongated, rounded, thick at base, tapering evenly to the small tips. Disk moderately swollen, the lesser to the greater radii

of the type as 1 : 4.4. The lesser radius of the type is 15 mm.; the greater radius, 66 mm.; breadth of rays at base, 18 mm.; diameter of madreporic plate, 3 mm.

The whole dorsal surface and sides of the rays are evenly covered with small well spaced pseudopaxillæ, each of which bears a fascicle, or more rarely a comb-shaped group of four to eight or more small slender spinules, which stand nearly erect, and are nearly equal in length. The pseudopaxillæ arise from elevations of the plates and are so spaced as to leave intervals greater than their own diameters, thus giving the surface a rough papillose appearance; the pseudopaxillæ are more closely arranged on the center of the disk than on the rays. The madreporic plate is large and covered with rough spinules in comb-like groups.

Each of the interspaces on the rays bears a single large papula, equal in diameter to or exceeding the pseudopaxillæ; similar papulæ occur between the ventral plates, where they form regular longitudinal rows. On the actinal surface of the rays there are three regular longitudinal series of plates corresponding in number to the adambulacral plates. The plates in the two outer or marginal rows are oblong at the summit, and each bears an oblong group of slender paxilliform spinules, arranged in two rows, and similar to those of the back. The plates of the superomarginal row are somewhat smaller than those of the inferomarginal, and the spinules are about twelve to fifteen in number toward the base of the rays, while in the latter there are from twenty to twenty-five spinules, which form pretty regular comb-like groups; these extend to the tips of the rays. Each of the interspaces alternating between these rows of plates contains a single large papula. Closely adjacent to the adambulacral plates there is a row of smaller peractinal plates, each of which bears a round group of small paxilliform spinules, ten to fifteen in number, similar in size and form to those of the marginal plates. This row of peractinal plates extends from the angle of the jaw nearly to the tip of the ray.

Each of the adambulacral plates bears a single small spine, situated deep within and directly across the furrow, forming a single longitudinal series, and also a transverse group, consisting of eight to twelve round, blunt spinules, in two rows; the three inner ones are decidedly longer and larger than the rest, the innermost odd one being the largest of the three, and standing erect on the extreme inner angle of the plate, and therefore nearly at right angles to the small spine within the furrow. The outermost spinules of these groups

are similar in size to those of the adjacent peractinal plates, from which they are separated by a distinct continuous groove. The jaws are covered with numerous erect spines, which are similar in size and form to those of the adambulacral plates, but the adambulacral plate nearest the mouth bears a group of small blunt spinules deep within the furrow.

Eastport, Maine, in shallow water, 1870 (coll. A. E. Verrill), type. Subsequently taken at several localities in the Bay of Fundy.

This variety is similar to typical *H. sanguinolenta* in form and general appearance, though the dorsal surface is more uneven and papillose, owing to the larger size of the pseudopaxillæ and the more regular interspaces; the pseudopaxillæ are generally more in the form of rounded fascicles in the latter, instead of regular comb-like groups. The differences are much more marked on the actinal surface, where the two regular rows of larger marginal plates and the regular row of peractinal plates give a very different appearance to this region; for in the typical form these plates are often scarcely distinguishable in size, form, and spinulation from those of the dorsal and lateral plates of the rays. The adambulacral and oral spines are also shorter and more crowded than in the common form.

This form, which was formerly (1894) fully described, as a distinct species, is of rather rare and sporadic occurrence on our coast, so far as known. It may be considered as a vigorous arctic or boreal variation of the species, due, perhaps, to unusually favorable conditions of climate and food. As I have now seen many specimens intermediate between this and the more usual forms of the species, it seems necessary to reduce it to the rank of a variety or subspecies.

This subspecies, like most others of the genus, is very variable in the character of the ossicles and spinules, as well as in color. The more common colors are either orange or purple, rarely lemon-yellow.

The type specimens of the variety were from Eastport, Maine. A very small specimen has been received from Popof Strait (W. H. Dall, U. S. Nat. Mus.). Some of those described by Fisher appear to be the same variety, especially his variety C. Some of the latter were very large; radii, 32 mm. and 235 mm.; or about nineteen inches in diameter. His variety C was taken at eleven stations in Bering Sea and near the Aleutian Islands, in 41 to 344 fathoms.

HENRICIA SANGUINOLENTA, Var. RUDIS Verrill, nov.

Plate LXXXVI, figures 5, 5a (details).

Rays five, large, thick, tapered to small tips. Disk large, swollen. Radii of the type, 22 mm. and 80 mm.; ratio, 1 : 3.14; breadth of rays at base, 25 mm. to 30 mm.

Dorsal surface covered with a multitude of very small, distinct parapaxillæ, forming a close reticulation, in which the small papular pores are mostly placed singly. The larger parapaxillæ bear a compact cluster of about five or six slender, tapered, acute, rough and rather long spinules; many of the smaller ones have three or four spinules. These give the surface a finely spinulose but rough appearance. There may be six to eight pseudopaxillæ to a square millimeter.

The adambulacral armature consists of a single or partially double transverse row, mostly of spatulate spinules. There are five to seven larger spinules in each group, and two or three outer ones that are much smaller, slender, and not flattened. The odd one on the inner angle, which is the largest one, is stout, wide at the truncate and grooved tip; up to 2.3 mm. long; the rest decrease gradually in size and amount of distal expansion to the most external ones. Adoral and oral spines are similar in size and form. The furrow-spine is single, small and slender.

The two rows of marginal pseudopaxillæ are small and scarcely distinguishable in the crowd of adjacent ones, all of which are spinulated like the dorsals. The inferomarginals are a little larger than the others and somewhat transversely elongated, bearing a transverse and slightly pectinate two-rowed group of slender spinules, about eight to twelve on the larger plates. The superodorsals are similar, when they are distinguishable, but in many places they are as small as the dorso-laterals. The peractinals are small and roundish. The type is from ten miles west of Point Franklin, Arctic Ocean, off the north coast of Alaska in 13½ fathoms, sand (coll. Murdoch, Point Barrow Expedition, No. 7623, U. S. Nat. Mus.).

This, though quite peculiar in respect to its adambulacral spinules, seems to be only an extreme variation of *H. sanguinolenta,* perhaps only an individual variation. I have seen no others like it, though some approach it to some extent.

HENRICIA SANGUINOLENTA MILIARIS Verrill, subsp. nov.

Plate LXXXVIII, figures 4-4*a*.

Rays five, well rounded, evenly tapered, and minutely spinulated. Proportions about as in the typical form of *H. sanguinolenta*. Radii of the type, 10 mm. and 38 mm.; ratio, 1 : 3.8.

The surface appears to the naked eye remarkably fine, smooth, and even, owing to the very small and uniform dorsal pseudopaxillæ. These are very numerous, distinctly separated, and rather closely placed, but not in contact nor forming rows or circles. They are mostly roundish, about as high as broad, and have about six to twelve very small, slender, acute, rough spinules. The papulæ are small and numerous between. The dorsal papulæ are mostly single, but often two or three together on an area.

On the actinal side, the two marginal series and the peractinals form three very regular and evident rows, and there is a very evident channel between the inferomarginals and peractinals, along which there is a very regular row of single papulæ, larger than those found elsewhere. Papulæ between the peractinals and adambulacrals are mostly lacking. When present, they are few and very small.

The adambulacral plates bear a single rather slender furrow-spine, and about twelve to fourteen on the actinal side, mostly in two crowded, graded rows. At the edge of the furrow there are three larger than the rest, one of which stands on the apex of the plates; two others, nearly as large, stand just back of the odd one, forming an oblique pair. The rest are graded so that the outer ones are single and of about the same size as the spinules of the adjacent plates. The inferomarginals are transversely oblong, about twice as broad as long, with about fifteen to twenty spinules, like those of the dorsal ossicles, but somewhat larger. The superomarginals are about half as large, of similar form; both rows are oblique.

The peractinals are roundish, very distinct, close to the adambulacrals, and have about eight to ten spinules in a stellate group. On some of the rays they extend nearly or quite to the tips. There is usually a short, subactinal row.

The type was taken off Cape Cod, Massachusetts, in shallow water, by the U. S. Fish Commission, 1879.

HENRICIA TUMIDA Verrill.

Plate XII, figures 1, 2; plate LXXXVII, figures 1, 1*a* (details).

Henricia tumida VERRILL, Amer. Naturalist, XLIII, pp. 554, 555, fig. 5, 1909.

Rays five, short and thick, acute; disk large, thick, swollen. The radii in the type are 11 mm. and 30 mm.; in another, 10 mm. and 22 mm.; ratios vary from 1 : 2.00 to 1 : 2.7.

The dorsal surface is thickly covered with small, rough pseudopaxillæ, which mostly surround large papular pores, each usually with a single papula. The papular pores are numerous and are found on nearly all parts, even between the peractinals and adambulacral plates. Most of the pseudopaxillæ are roundish or elliptical and bear from six to twelve spinules; the larger ones are narrow-oblong, and have about two rows of spinules, often amounting to twenty to twenty-five. Frequently the pseudopaxillæ are crowded and appear to blend together in circles around the papulæ. The spinules are elongated, slender, with rough, thorny or spiculose tips.

The adambulacral plates and spines are relatively large; each plate bears a rather short intra-ambulacral or furrow-spine, and a transverse row of four to six on the actinal side. The first three of these are larger and divergent, elongated, and obtuse. The others are smaller and graded.

The inferomarginals form regular rows; they are strongly compressed and bear about twelve to twenty small, slender spinules. The superomarginals are smaller, oblong, oblique, compressed, with similar but fewer spinules, like those of the dorsals. The peractinals are small and extend to about the distal fourth. They have four to six spinules; they are close to the adambulacrals; one or two very short intermarginal rows, or a small group, may be present close to the base of the ray. They are similar to the superomarginals and dorsals in spinulation.

The central part of the disk and oral region are deeply withdrawn, forming a funnel-like pit. The interradial actinal areas are closely folded inward, and about eight or nine adambulacral plates in each row are included in the incurved portion of the actinal surface. These plates and their spines rapidly decrease in size adorally, those near the jaws being less than half as large as the eighth or ninth. There are two short, stout, apical peroral jaw-spines, and about six small epiorals.

This species or "form" is easily distinguished by its large, swollen disk and short rays, and by the deeply sunken oral region.

The dorsal surface is nearly as in *H. borealis,* except that the ossicles are usually smaller and the spinules are more numerous and in smaller clusters, and often stand in small, rounded or oblong groups around the papulæ.

The marginal, actinal, and adambulacral plates and spines are nearly the same as described under *H. borealis,* but in some specimens the superomarginal row of plates is not separated, proxi-

mally, from the lower row by interpolated plates and is, therefore, more regular and distinct. Its broad disk and very short rays are shared by *H. arctica;* but in the latter the disk is flat and the oral region is not sunken, while the spinulation is very minute, and the spinules far more numerous and differently arranged on all the plates, but particularly on the adambulacrals.

Dutch Harbor, Unalaska (Harriman Expedition, Dr. W. R. Coe).

The name *tumida* was originally a manuscript name used on labels by Dr. Richard Rathbun, who had recognized this as a distinct form several years ago.

This is a very peculiar form of *Henricia,* having a large, swollen disk and very short rays, but in most other respects agreeing so closely with *H. borealis* that it seems possible that it is only a sexual form or a variation of the latter.

The peculiar excavate condition of the actinal surface of the disk and oral area seems to be specially adapted to the carrying of the eggs and young. Whether all the specimens were actually females could not be determined from dry specimens. It might be thought that this is the normal female, while *H. borealis* is the male of the same species, were it not that Dr. Fisher has figured the female of *H. borealis,* while actually carrying eggs, and it does not agree with *H. tumida,* but has about the proportions of *borealis,* and arches its disk as is usual in other species of the genus. There is no evidence given that the arching is persistent, nor that the adoral plates and spines are modified for that purpose.

HENRICIA TUMIDA BOREALIS Verrill, subsp., nov.

Plate XII, figures 3, 4; plate LXXXVI, figures 6-6*a* (details); plate LXXXVIII, figures 5-5*b* (details).

Henricia eschrichtii (*pars*) FISHER, op. cit., 1911*b,* p. 276, pl. LXVII; pl. LXVIII, fig. 1 (*non* Müller and Troschel).

Rays five, short or moderately long, stout, swollen at base, tapering rapidly to slender tips. Disk rather large and thick. Radii of a dry specimen, 12 mm. and 42 mm.; ratio, about 1 : 3.5. Breadth of rays at base, 15 mm. Another specimen has the radii 11 mm. and 42 mm.; ratio, about 1 : 3.8. A short-rayed specimen has the radii 10 mm. and 24 mm.; ratio, 1 : 2.4.

The dorsal surface, in dry specimens, has a distinctly areolate appearance, the angular meshes of the network of ossicles being larger and deeper than usual in the related species, and the narrow

ossicles everywhere covered with even, fine, slender, upright, crowded spinules, which largely stand in two or three close rows on the larger ossicles, and sometimes in single, comb-like rows, around and between the papulæ. The larger groups are often curved or crescent-shaped. These spinules are longer and more slender than in ordinary *H. sanguinolenta,* and have rough, acute, or subacute tips. They diverge but little. The papular pores are rather large and mostly isolated. The madreporic plate is of fair size, rough, with rows of small spinules on the gyri.

The dorsal ossicles, when the spines are removed, are small, thick, convex, often narrow-oblong. They form an open reticulation in which the smaller meshes are polygonal or irregularly triangular. The upper and lower marginal plates are easily distinguished by their larger size and more convex surface. The two rows are contingent on the distal third of the rays, with large papular pores between them. They become separated by a row of small rounded ossicles, increasing in size proximally. Two or three other rows of small, irregular intermarginal ossicles are also interpolated at the base of the rays, in the lateral interradial areas, where the upper and lower marginals are widely separated. The superomarginals are prominent, with a narrow transversely oblong surface. The inferomarginals are larger, with the exposed surface sometimes angular, or transversely oblong, sometimes curved or crescent-shaped, with a narrow, prominent ridge for the insertion of the spines. They are always decidedly longer transversely to the rays; the transverse diameter is often double the longitudinal. When curved, the convexity is toward the base of the ray. Some of the proximal ones are much compressed, with a rather sharp ridge, and bear only one row or comb of spinules.

The peractinal ossicles form but one row, though often the row is irregular. They are somewhat rounded or lobate lozenge-shaped, and much smaller transversely than the inferomarginals, but equal to them in number. The two rows are united by apophyses, between which is a row of large papular pores. They are united directly to the adambulacral ossicles, with which they agree in length. The latter are transversely oblong and prominent.

The spinules on the superomarginal and lateral ossicles are about the same as those of the dorsal surface, but on the inferomarginal plates they become a little larger and longer. On the inferomarginals they mostly stand in two rows, of about eight to sixteen each, along the middle of the rays; but beneath the disk they may be reduced to

a single comb-like row of six to twelve, on some of the plates. The peractinal plates bear a smaller double group of similar spines, mostly six to ten in number. The spines on the actinal surface of the adambulacral plates stand in two rows, or often only one row distally, increasing regularly in size and length to the one or two unpaired ones at the edge of the groove. These are rather large, slightly clavate, and obtuse. The intra-ambulacral spine is much smaller and shorter, acute or subacute. not very slender. The two apical peroral spines are rather stout, subacute; the epiorals and adorals are similar.

Taken at Dutch Harbor, Unalaska, Yakutat, Fox Cape, Sitka, etc. (Harriman Expedition). Common.

Recorded by Dr. Fisher (as *eschrichtii*) from numerous localities between Bering Straits and Yakutat, Alaska, from the shore to 86 fathoms, and on the Asiatic side to Kamchatka and the Kuril Islands.

Dr. Fisher records specimens of this species carrying eggs, taken June 8, 10, and 14, 1906; and one carrying young up to 4 mm. in diameter with eight pairs of ambulacral feet to each ray; taken by the "Corwin," in Bering Sea. (See Fisher's pl. LXVIII, fig. 1.)

Probably this subspecies has formerly been confused with *H. sanguinolenta,* which it much resembles, superficially.

It can best be distinguished from *H. sanguinolenta* by the larger and decidedly transversely oblong inferomarginal ossicles and their clusters of spines, of the same form. These plates in *H. sanguinolenta* are usually smaller, scarcely oblong, and bear smaller divergent clusters of spines. This is also, in most cases, a stouter species, with shorter rays and much larger disk. Other differences appear on closer examination, especially in the dorsal skeleton and marginal plates, and in the much narrower and simpler rows and longer adambulacral spines.

It is so unlike *H. leviuscula* that there is no need to compare the two, in detail.

This subspecies is, apparently, quite unlike *H. eschrichtii* Müller and Troschel, as already remarked. The latter was described as having the proportions 1 : 4, or about those of ordinary specimens of typical *H. sanguinolenta,* from which it differs less than var. *pectinata,* or subsp. *miliaris.* I consider it nearly the same as var. *pectinata.*

One specimen, taken with the type of *H. tumida,* has nearly the same spinulations as the latter, both above and below, and yet does not have the oral region inarched. It has, however, a somewhat smaller and less turgid disk. Its radii are 8 mm. and 20 mm.; ratio, 1 : 2.5.

Some of the varietal forms referred to *H. sanguinolenta* by Fisher appear to me to belong rather with *borealis,* especially those on pl. LXVIII, fig. 3.

It is not unlikely that *H. borealis* may be the male form of *H. tumida.* Should that prove to be the case, the latter name has priority.

HENRICIA ARCTICA Verrill, sp. nov.

Plate LXXXVII, figures 3-3*c* (details); text-figure No. 13.

Henricia eschrichtii (*pars*) FISHER, op. cit., 1911*b*, p. 276, pl. LXVIII, fig. 2 (*non* Müller and Troschel).

Form stellate, with a wide disk and short, thick rays. Radii of the type, 13 mm. and 28 mm.; ratio, 1:2.15; breadth of rays at base, 15 mm.

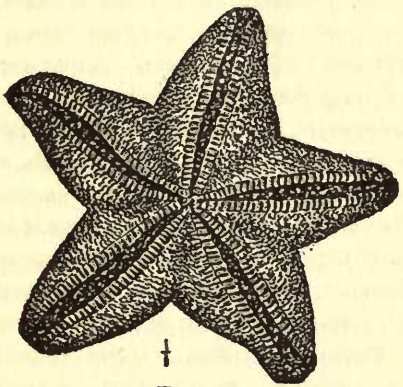

FIG. 13.

Henricia arctica Ver., type. U. S. Nat. Mus. Actinal side, natural size.

The disk, as preserved, is but little convex dorsally, and nearly flat on the actinal side, with no marked oral concavity, the jaws and oral spines being fully exposed, not sunken in a deep concavity as in *H. tumida.*

The dorsal ossicles are very small and closely united into a very fine-meshed reticulation, with small, single papular pores. The small pseudopaxillæ are covered with compact groups of very small, short spinules of nearly uniform length, ten to fifteen or more on the larger ones, often only four to six on the smaller ones. They produce a pretty even, almost granular-appearing surface, of fine texture. Very often four to six small pseudopaxillæ form a rosette-like group around a papular pore.

The spinules are smaller and shorter than in any other North Pacific or Arctic species known to me, and the surface is correspondingly more even and finer-grained.

The two marginal rows and the peractinal row of plates are distinct, but not conspicuous and not very regular. The inferomarginals are larger than those of the other rows. They are obliquely placed and transversely compressed proximally, but become more elliptical or rounded and more irregular distally. They bear a close cluster of minute spinules like those of the dorsals. The inferomarginals are smaller and scarcely distinguishable in many places. There are two or three short rows of intermarginals proximally. The peractinal plates are pretty regular, oblique, mostly rhombic, smaller than the inferomarginals, and spinulated in the same way.

The adambulacrals bear several close irregular rows of very short, and very small, obtuse spinules, about five to eight in each row,[1] not very unlike in size, and an odd one slightly larger on the inner angle; the furrow-spine is very small and short. The adoral and oral spines are larger, obtuse, numerous and crowded.

This species appears to be more distinct from all the other North Pacific forms of the genus than most of those hitherto described, at least from the shallower waters.

Why Dr. Fisher should have united it with his *H. eschrichtii* is not easy to understand, for there is no particular resemblance to that species, unless in the short rays; but in this respect the present species exceeds all others except *H. tumida.*

From the latter it differs widely in the much finer and shorter dorsal and marginal spinules, in the smaller and closer ossicles, and especially in the very different character of the adambulacral spinules, which are much longer and fewer in *H. tumida,* and in a single row. The latter, moreover, has a deep concavity around the oral region, in which the jaws and oral plates are so deeply sunken as to be seen with difficulty. Possibly this last character pertains only to the female, as suggested above, but in that case the other characters named are ample for distinguishing the two forms.

The type of this species was from off Cape Lisburne, Alaska (coll. H. D. Woolfe, No. 12,818, U. S. Nat. Mus.). The specimen figured by Fisher is from the same vicinity.

[1] The figure (pl. LXXXVII, fig. 3*a*) represents these spines as too few and too large. In the specimen figured the spines were badly worn off from most of these plates.

HENRICIA LONGISPINA Fisher.

Henricia longispina FISHER, op. cit., 1910, p. 572; 1911*b*, p. 299, pl. LXXVI, figs. 1, 2; pl. CXI, figs. 3, 3*a*.

Rays five, moderately slender, cylindrical. Radii of type, 9 mm. and 47 mm.; ratio, 1:5.2. Dorsal ossicles are stout and form a rather coarse and open reticulation. Spinules are spaced in fasciculate groups of two to nine, mostly five to seven, unusually long for the genus, up to 1 mm. to 1.5 mm., acute and finely denticulate. Marginal rows of plates fairly regular, not very large, each with six to nine spinules. The inferomarginal spines are a little the larger; somewhat transversely elongated; two or three intermarginal rows of small plates proximally, the longest extending to one-half to two-thirds the length of the ray; interradial plates small, extending to about half the length of the ray, with two to four spinules. Papulæ exist between the interactinal and adambulacral plates, as in most species of the genus. Adambulacral plates have one saber-shaped furrow-spine; on the actinal margin a long, tapered spinule with two smaller ones seated back of it, followed by three or four smaller and shorter, acute, graded spinules, the whole series forming a zigzag or irregular transverse row. The adambulacral spines are longer than any others.

Color in life, milk white.

The type was from Queen Charlotte Sound, off Vancouver Island, in 68 to 107 fathoms, soft mud. The only other locality is Naha Bay, Behm Canal, southern Alaska, in 41 to 134 fathoms, gravel.

The description is abridged from that of Professor Fisher.

HENRICIA ASPERA Fisher.

Henricia aspera FISHER, op. cit., 1911*b*, p. 293, pl. LXXV, figs. 1-5.

Stellate, usually with five long, slender rays. Radii of type, 15 mm. and 100 mm.; ratio, about 1:6.6; sometimes 1:7.2, and 1:5.3.

Dorsal plates openly reticulated, the spinules not grouped into evident pseudopaxillæ, but short, granule-like and nearly continuous over the lines of ossicles around the papular pores; the meshes and papular areas rather large, each with several, five to twelve, papulæ in adults. Spinules stout, sharp, not crowded, often obscured by membrane; the rows often interrupted.

Marginal plates in regular rows, the upper ones usually a little smaller, spinules about ten to twelve to a plate. Interactinal plates

in two rows proximally. Adambulacral plates have one or two furrow-spines proximally; on actinal side two larger stoutish spines obliquely placed; and outside these, three or four smaller graded spines in an irregular transverse row.

Mr. Fisher records this from numerous localities in 26 to 313 fathoms, from Bering Sea to Santa Barbara, California.

The above description is condensed from Fisher.

Family *SOLASTERIDÆ* Perrier.

Solasterinæ (sub-family of Echinasteridæ) VIGUIER, Squelette des Stellérides, Nouv. Arch. Zool. Expér., VII, p. 133, pl. VIII, figs. 1-7, 1878 (structure).

Solasteridæ PERRIER, Etoiles de mer, p. 210, 1884. Sladen, Rep. Voy. Chall., Zool., XXX, p. 442, 1889. Perrier, Expéd. Trav. et Talism., p. 151, 1894. Fisher, op. cit., 1911*b*, p. 305.

Echinasteridæ (*pars*) PERRIER, Révis. Stell., Nouv. Arch. du Mus., IV, p. 358, 1875.

Rays varying in number from five to thirteen or more. Dorsal skeleton generally formed either by openly reticulated or loosely imbricated (rarely detached, *Lætmaster*) ossicles, which have a convex or elevated central boss, bearing a cluster of slender, paxilliform, movable spinules, webbed together into a stellate or penicillate group (pseudopaxillæ). Both series of marginal plates are usually distinguishable, at least distally, alternate or opposite, or in one line. The upper ones are often the smaller and essentially like the dorsal pseudopaxillæ. Both rows bear paxilliform spinelets.

Actinal interradial pseudopaxillæ are generally present and similar to the dorsals. Adambulacral plates are transversely elongated and bear, each, one to five or more spines, often webbed, in a longitudinal row on the inner margin of the groove, and one or more clusters or a transverse webbed series or comb of movable spines on the outer surface. True pedicellariæ are not known in most species; but large specimens sometimes have a few small, bifid spines in the furrow series, and in *S. stimpsoni* a few minute bivalve pedicellariæ sometimes occur on the dorsal paxillar areas. Tube-feet have suckers.

Sladen (1888 and 1889) divided this family into two subfamilies: Solasterinæ and Korethrasterinæ. In this he was followed by Perrier (1894, pp. 154, 158). Later these have been considered separate families.

Genus **Solaster** Forbes.

Solaster (*pars*) FORBES, Mem. Wern. Soc., VIII, p. 120, 1839; British Starfishes, p. 109, 1841. Gray, Ann. and Mag. Nat. Hist., VI, p. 183, November,

1840; Synopsis, p. 4, 1866. VERRILL, Proc. Boston Soc. Nat. Hist., x, p. 345, 1866 (*Solaster* and *Crossaster* first separated). Agassiz, North American Starfishes, pp. 111, 112, 1887 (structure). Perrier, Expéd. Trav. et Talism., p. 154, 1894. Sladen, op. cit., p. 450, 189.

Crossaster (*pars*) MÜLLER and TROSCHEL, Monatsb. Preuss. Akad. Wiss., Berlin, April, 1840, p. 103.

Solaster (*pars*) VIGUIER, Nouv. Arch. Zool. Expér., VII, p. 138, 1878 (structure). Bell, Catal. Brit. Echinod., p. 88, 1892.

Solaster (*pars*) DANIELSSEN and KOREN, Norw. N. Atlantic Exp., Asteroidea, pp. 42, 52, 53, 1884 (structure). Fisher, op. cit., 1911*b*, 306.

Disk rather broad. Rays seven to twelve, variable in each species. Dorsal ossicles small, mostly subcruciform or slightly four-lobed, sometimes stellate, usually reticulated, or in quincunx, on the disk and proximal part of the rays, but closely imbricated near ends of the rays, and often arranged in regular quincunx order; sometimes united by smaller ossicles. They are convex or slightly mammillate, with a central boss, and bear a stellate or fasciculate cluster of slender spinules, webbed together, and usually enclosing one or several central spinules, connected by the web, forming pseudopaxillæ. The outer circle of webbed spinules often forms a funnel-shaped structure in life, or when well preserved; but the spinules are movable, and in dry specimens they are usually mostly collapsed or tipped over, thus forming irregular groups or pencils or small spinules, from five to twenty or more in a group.

The superomarginal plates are small and close to the larger inferomarginals, usually alternating. They are usually hardly distinguishable from the dorsal pseudopaxillæ, except near the ends of the rays, but they extend regularly to the apical plate.

Inferomarginals much larger and more elevated, transversely oblong, forming a rather conspicuous row. They bear a large number of paxilliform spinules in two or more transverse rows. Adambulacral plates usually have two to four shorter groove-spines, webbed together, and an actinal transverse row of four to nine or more longer spines, also webbed.

The interradial actinal areas are small, but distinct, and bear pseudopaxillæ, much like the dorsal ones.

Papulæ are numerous on the dorsal surface, but stand singly or in small groups. A single row of peractinal pseudopaxillæ usually extends along the proximal part of the rays, to about the middle.

The eggs and young are carried attached to the oral region in clusters in *S. endeca* and other species.

The structure of the skeleton has been very fully described and beautifully illustrated by Agassiz in the work cited above.

The species of this genus, like those of *Henricia* and *Leptasterias*, are numerous and variable, presenting in many cases puzzling forms, due, perhaps, to hybridism or to the localization of accidental varieties or "sports," and made possible by the habit of the parents to carry and care for the eggs and young, which have no free-swimming stages. (See remarks under *Leptasterias*, pp. 116, 117.)

SOLASTER ENDECA (Linné) Forbes.

Plate IX, figures 2, 3 (young); plate LXXXVII, figures 4-4*b* (details); plate LXXXIX, figure 1 (typical).

Asterias endeca LINNÉ, Mant. Plant. App., p. 543, 1771. Retzius, K. Svenska Vet. Akad. Handl., IV, p. 237, 1783. Gmelin, Syst. Nat., p. 3162, 1788. Lamarck, Anim. s. Verteb., II, p. 560, 1816.

Solaster endeca FORBES, Mem. Wern. Soc., VIII, p. 121, 1839; Hist. British Starfishes, p. 109 (fig.), 1841. Müller and Troschel, Syst., p. 26, 1842. Gray, Ann. and Mag., p. 183, 1840; p. 19, 1848; Synopsis, p. 5, 1866. Stimpson, Invert. Grand Manan, p. 14, 1853. Lütken, Oversigt over Grönlands Echinodermata, p. 35, 1857. Verrill, Proc. Boston Soc. Nat. Hist., X, pp. 345, 356, 1866; Bull. Essex Inst., III, p. 4, 1871; Amer. Journ. Sci., V, p. 104, 1873; Expl. of Casco Bay, p. 356, 1874. Perrier, Stellérides du Mus., in Arch. Zool. Expér., IV, p. 359, 1875. A. Agassiz, N. Amer. Starfishes, p. 112, pl. XVII, figs. 1-5, 1877. Viguier, Squelette des Stellérides, Arch. d. Zool. Exp. et Gén., VII, p. 134, 1878. Duncan and Sladen, Echinod. Arctic Sea, p. 40, pl. III, figs. 5-8, 1881. Danielssen and Koren, Norske Nordshav. Exp., XI, p. 50, pl. IX, fig. 13, 1884. Verrill, Results Expl. by Albatross in 1883, p. 541, 1885. Murdoch, op. cit., 1885, p. 160. Ganong, Echinod. New Brunswick, p. 33, pl. I, fig. 8, 1888. Fewkes, Bull. Essex Inst., XXIII, p. 63, 1891. Bell, Catal. British Echinod., p. 90, 1892. Verrill, Amer. Journ. Sci., XLIX, p. 199, 1895 (distribution). Ludwig, Fauna Arctica, I, p. 464, 1900 (synonymy and distribution). Clark, op. cit., 1904, p. 556, pl. III, figs. 12, 13; pl. IV, fig. 23. Fisher, op cit., 1911*b*, p. 307, pl. LXXXI; pl. LXXXII, figs. 1, 2, 4.

A very large ten-rayed, typical specimen, collected by Mr. N. P. Scudder, off the coast of Greenland (lot 61), has the following characters:

Radii, 76 mm. and 190 mm.; ratio, nearly as 1:2.5. The adambulacral plates, opposite the bases of the rays, mostly bear two unequal, short furrow-spines, and a smaller rudimentary or pedicellaria-like spine; on the ventral side they bear an obliquely transverse group of eight to fifteen longer and stouter graded spines, of which the inner ones are longer, the first two being considerably longer and placed nearly side by side. They are partially webbed together and often stand more or less in two alternate rows. Outside each of these, but often almost blending with them, there is a group of fifteen to

twenty or more smaller actinal spinules, standing irregularly in about three transverse rows on each peractinal plate. Farther out they rapidly decrease in number and disappear at about the middle of the free part of the ray. Outside these there is a conspicuous row of inferomarginal pseudopaxillæ, distinctly larger than the others. Each of these plates bears about thirty to forty small, slender, rough, subacute spinules, in three or four divergent rows. The actinal interradial plates bear clusters of spinules (pseudopaxillæ) similar to those of the lower marginals, but a little smaller and more compressed, and mostly webbed together laterally. They are radially arranged and rather numerous, forming about sixteen to twenty rows, covering a rather large acute-triangular interradial area.

The superomarginal groups are much smaller, but prominent and unequal in size; the largest are ovate or oblong-ovate, bearing twenty to thirty small acute spinules in about three or four divergent rows. They are close to the inferomarginal ones and alternate with them. The dorsal pseudopaxillæ are rather small and unequal in size; the larger are oblong-elliptical; the smaller oval or round; all are covered with minute divergent spinules of nearly uniform length. The smaller plates bear about seven to nine spinules; the larger fifteen to twenty or more. When expanded they are stellate and webbed together, with two or three in the middle. Madreporic plate large and irregular, with somewhat enlarged and prominent pseudopaxillæ surrounding it. The papulæ are large and numerous; they mostly stand singly or two together in the interspaces between the plates.

Greatest diameter, 15 inches, or 382 mm. Radii of disk, 3 to 3.5 inches, or 76 mm. to 89 mm. Radii of rays, 7 to 7.5 inches, or 178 mm. to 190 mm. Breadth of rays, at base 2 inches, or 51 mm.

Another very similar specimen from the Fishing Banks off Nova Scotia (lot 820) has nine rays. Its dimensions are as follows:

Greatest diameter, 13.50 inches, or 344 mm. Radii of disk, 2.75 to 3 inches, or 70 mm. to 76 mm. Radii of rays, 6.50 to 6.75 inches, or 166 mm. to 174 mm. Breadth of rays at base, 1.75 inches, or 44 mm. Ratios of radii, about 1 : 2.5.

The dorsal pseudopaxillæ are so close that when the spinules are fully spread out or naturally expanded in the stellate and webbed condition, they nearly or quite touch each other, leaving room only for the mostly solitary papulæ between them. They are nearly uniform in character over the disk and rays, though variable in size. On the sides of the rays proximally they are arranged pretty

regularly in alternating obliquely transverse rows, or in quincunx, and are a little larger and bear twelve to eighteen or more divergent webbed spinules around the edge and four to six or more on the central part. On the distal part of the rays the ossicles become smaller, more closely crowded, and imbricated, with their regularly stellate spinules in contact. Many of these have only nine to twelve spinules around the edge and one to three in the middle.

The adambulacral plates mostly bear two unequal furrow-spines, but some proximal ones bear three, the central much the larger; distally they mostly have but one.

NORTH PACIFIC SPECIMENS.

A ten-rayed specimen taken off Kadiak, Alaska, in 5 fathoms, by the Harriman Expedition, agrees well with New England specimens of the same size. Its color in life was "orange with purple bars" (Coe).

Radii, 25 mm. and 65 mm.; ratios, about 1:2.6. The rays are convex above and taper to rather slender tips. Dorsal surface closely and evenly covered with small, stellate pseudopaxillæ, which do not form any distinct radial rows, but often are in contact by their edges. When expanded they are unequal, mostly circular and regularly stellate, each having from nine to fifteen or more minute, divergent spinules, webbed together around the edge, and two to four in the middle. They are borne on very small, convex, mostly four-lobed ossicles, between which are numerous isolated papular pores, each of the larger pseudopaxillæ having three to five around it. On the sides of the rays the pseudopaxillæ are in pretty regular quincunx order.

Central (nephridial) pore distinct. Madreporic plate large, with several pseudopaxillæ on its surface.

Superomarginal pseudopaxillæ small, but more than twice as large as the dorsals, with numerous larger, closely clustered spinules. They are round or ovate, close to the upper side of the inferomarginals, with which they alternate.

The inferomarginals are much larger and more prominent, transversely oblong, elliptical, and convex or rounded at the summit, and covered with minute, rough, acute spinules, like those of the back, but rather larger. Of these about twenty-five to forty surround the margin, while about fifteen to twenty form a central row.

A row of peractinal plates extends to about the middle of the free part of the rays, decreasing rapidly distally. The proximal ones are

similar to the inferomarginals, but smaller and less prominent. The interradial areas are rather large, acute-triangular, and covered with oblong or elliptical unequal pseudopaxillæ like the synactinals, but smaller.

The adambulacral plates have each two, or sometimes three, short, acute, unequal, divergent furrow-spines, reduced to one distally. Their actinal surface bears a row of about six or seven graded spines, the inner one and that next to it being distinctly larger than the rest and standing obliquely on the plate. These spines are webbed together, and proximally stand in a curved transverse row.

The four inner peroral spines at the apex of the jaws are large and stout, subacute, the two median ones larger. They are flanked on each side by about six smaller, tapered furrow-spines, decreasing in length distally. On the actinal side of the jaws there are two longitudinal curved rows of epioral spines, webbed together, seven or eight in each row, increasing in size adorally, the inner one in each row distinctly larger.

The color in life is usually either orange-yellow or purple, rarely lemon-yellow.

This species has a very extensive geographical distribution. It is circumpolar, occurring at Greenland, Spitzbergen, Nova Zembla, Iceland, and on the northern coasts of Europe and Asia, as far south as Great Britain and East Siberia.

On the Atlantic coast of America it is common as far south as Cape Cod. It was taken by the U. S. Fish Commission at numerous stations, in 5 to 150 fathoms, from Newfoundland to Cape Cod. Common on the eastern coasts of Maine and Massachusetts, and in the Bay of Fundy, from low water to 90 fathoms, and off Cape Cod, 20 to 50 fathoms. Taken on all the fishing banks off Nova Scotia, in 20 to 150 fathoms.

On the northwest coast of America it is common in Bering Sea and northern Alaska, and extends southward to Sitka. I have studied specimens from Yakutat, and from off Juneau, Alaska, in 20 fathoms (Harriman Expedition).

I have also examined one rather large, tumid, nine-rayed specimen, in alcohol, from Bering Island (N. Grebnitsky, U. S. Nat. Mus.). It has previously been recorded from Barents Sea, Kara Sea, and East Siberia.

Dr. Fisher records it from off the Shumagin Islands; Kasaan Bay; and Kadiak, Alaska, in 12 to 123 fathoms; and from Queen Charlotte Sound, in 238 fathoms.

The dorsal surface of this species is closely covered with smaller pseudopaxillæ, having finer and more numerous spinules, than in any other west American species, except *S. galaxides,* in which they are still smaller.

It is allied to *S. stimpsoni* Verrill, from the Northwest coast of America; *S. subarcuatus* Sladen, from the Southern Indian Ocean, S. lat. 52° 04′, in 150 fathoms; and *S. torulatus* Sladen, from north of the Kermadec Islands, in 250 fathoms.

TERATOLOGY.

A medium-sized specimen, taken at Eastport, Maine, has ten rays, but one of the rays forks beyond the edge of the disk, the two forks becoming like the other rays, in size and form, distally, so that it becomes eleven-rayed. Otherwise it has the ordinary characters of the species.

Specimens with nine rays and twelve rays are not very rare. Those with ten rays are about as common as those with eleven rays.

SOLASTER GALAXIDES Verrill.

Plate XLVI, figures 2, 2*a* (type); plate LXXXVII, figures 5-5*c* (details, cotype); plate LXXXIX, figure 2 (actinal side, type).

Solaster galaxides VERRILL, Amer. Journ. Sci., XXVIII, p. 59, figs. 2, 2*a*, 1909.

This is a broad-disked species, usually with nine or ten rays, covered above with very small, flat-topped, crowded pseudopaxillæ, and resembling *S. endeca* in form and color. The two type specimens have nine rays. The larger has the radii 40 mm. and 110 mm.; ratio, about 1 : 2.7. It was orange-color in life.

The marginal spines are about as in *S. endeca,* but the inferomarginals are more elongated transversely, and bear a decidedly greater number of more minute spinules.

The peractinal series of pseudopaxillæ extends only to about the basal third of the free part of the ray. They are relatively smaller than in *endeca,* being here only about half the size of the inferomarginals proximally.

The actinal interradial areas are apparently relatively larger than in *endeca* of the same size and number of rays, and bear a larger number of compressed pseudopaxillæ, the larger ones similar to the inferomarginals and peractinals. They form about sixteen radial rows, the smaller one in the median rows distally. They are covered with a large number of small, rather short, regular spinules.

The dorsal ossicles are unusually small and closely united, leaving very small papular pores, and the pseudopaxillæ are uncommonly small, with a small flat-topped fascicle of about twelve to sixteen minute spinules, of which three to six usually occupy the central area.

These pseudopaxillæ are only about half as large as in typical Atlantic specimens of *endeca* of corresponding size. There are usually two subequal, rather long, acute, divergent furrow-spines on each adambulacral plate, only one distally. On the actinal surface the curved transverse row or comb has usually six to eight graded spines, the two inner decidedly longer and stouter.

The oral spines and jaw-spines are much better developed than usual. The four apical spines are very large, strong, and acute. There are six graded furrow-spines on each side. The epioral spines are long and slender. They form two subparallel rows of about eight or nine graded spines. The spines in the opposed rows are often bent toward each other and interlocked. The two most adoral are distinctly larger than the others.

Two typical specimens from Victoria were received from the Provincial Museum of British Columbia. Another, very similar in character and size, is from Friday Harbor, Puget Sound, cotype, No. 1897, Mus. Comp. Zoöl., pl. LXXXVII, figs. 5-5*c*.

SOLASTER DAWSONI Verrill.

Plate XLVI, figures 5-5*b* (details); plate XC, figure 1 (15-rayed); plate XCI, figures 1, 2; plate XCII, figure 1 (13-rayed).

Solaster dawsoni VERRILL, in Whiteaves, Report Prog. Geolog. Survey Canada, 1878, 1879, p. 4. Whiteaves, Trans. Royal Soc. Canada, IV, sect. 4, p. 116, 1886. Fisher (*pars*), op. cit., 1911*b*, p. 313, pl. LXXXIV, figs. 1, 2; pl. LXXXV, figs. 1, 2; pl. LXXXVI, figs. 1, 2; pl. CXIII, fig. 1.

The type has the following characters: Rays twelve. Radius of the disk, 20 mm.; of the rays, 53 mm.; ratio, about 1:2.62. It is less than half grown.

It has the general appearance of *S. endeca,* as seen from above, but resembles *Crossaster papposus* beneath. The dorsal pseudopaxillæ and their clusters of stellate spinules are small, numerous, and crowded. Usually there are ten to fifteen minute, short, webbed spinules around the edge of each plate. The plates, when denuded of spines, are small, three- and four-lobed, closely imbricated, with a rounded and convex central mammilla. The inferomarginal plates are prominent, and each bears a prominent transverse group of numerous small, slender spinules, forming two rows of about twelve to fourteen each.

The interradial spaces, beneath, are very small and narrow, with very few ossicles, each of which bears a group of three or four slender, elongated spinules. These spaces are very much smaller than in *S. stimpsoni*, and still smaller as compared with *S. endeca*. The adambulacral plates bear a longitudinal group of three, or sometimes four, long, slender, furrow-spines, and outside of these a transverse group of four or five rather larger and longer ones. The oral plates bear six long, slender blunt preoral spines, the two middle ones longest, and four or five small lateral ones on each side.

The adambulacral spines, especially the furrow-series, are much longer than in *S. stimpsoni* and *S. endeca*, both of those usually having but two small and short furrow-spines on each plate in specimens of similar size.

This type was from Virago Sound, British Columbia, in 8 to 15 fathoms (G. M. Dawson, Canadian Geological Survey). It was dried and not in a good state of preservation. Much larger and better specimens have subsequently been obtained, many of which have been sent to me by the Canadian Geological Survey.

One of the larger dry specimens from Powell Island, Straits of Georgia, has the radii 34 mm. and 100 mm.; ratio, about 1 : 3. (Pl. XCI, fig. 2; XCII, fig. 1.)

Rays thirteen, rather long and narrow, tapering gradually, the disk being smaller and the rays rather longer than is usual in *S. endeca*.

The dorsal pseudopaxillæ, many of which are preserved expanded, are small, crowded, regularly stellate, with a truncate or infundibuliform top, surrounded by about twelve to eighteen small, slender spinules, webbed together, and mostly with one to three very small central spines, though many have more.

The plates are small, partly four-lobed and partly three-lobed, with a prominent central mammilla. They are everywhere closely imbricated, mostly arranged in quincunx order, and on the sides of the rays they stand in close and pretty regularly alternating oblique rows.

The papulæ are numerous and small; they stand partly in small groups and partly singly.

The madreporic plate is large and prominent, with numerous fine gyri, and with three or four pseudopaxillæ on its surface, near the margin.

The inferomarginal plates are large and very prominent, transversely oblong, with thirty to forty or more very slender spinules

around the margin, and one or two smaller rows on the summit. The spines are decidedly longer than those of the dorsal surface, especially the inferior ones.

The superomarginal plates and pseudopaxillæ are unusually distinct and well developed. They are rounded and bear a regularly stellate group of twenty to thirty slender spinules, longer than those of the dorsal ossicles.

The interradial areas are very small and narrow, with a few (about twenty) irregular ossicles, which bear round pseudopaxillæ, having from five to ten long and slender spinules. None of the interactinal plates extend on the rays beyond the margin of the disk.

The furrow-series of adambulacral spines stand mostly four to a plate, often with a small fifth one proximally; they are long, slender, divergent, webbed together, the middle ones longest, and about as long as those of the transverse series. The latter are unusually long and slender, subequal; they usually stand five in a row, but often six.

The six terminal peroral spines are rather long, but not very stout; they are regularly graded, and there are five or six in each adoral lateral row.

There are two pairs of epioral spines, the proximal pair being much the longer.

VARIATIONS.

A dry, twelve-rayed specimen, a little larger than the last, but having the same proportions, from Queen Charlotte Islands, has somewhat larger dorsal pseudopaxillæ, mostly with twelve to fifteen somewhat stronger spinules. The furrow-series of spines stand mostly three to a plate, but sometimes four; they are about as long as, and rather more slender than, the transverse series.

Another specimen from the same locality has thirteen rays. The radii are 28 mm. and 85 mm.; ratio, 1 : 3. The dorsal pseudopaxillæ are smaller, elegantly stellate, with about twenty to twenty-five slender spinules. The madreporic plate has a remarkably fine texture. It is partly concealed by a circle of about ten stellate pseudopaxillæ that stand partly within its margin. The furrow-spines proximally often stand four on a plate, though more commonly three to a plate, the different rays differing in this respect at corresponding places. The transverse rows of pectinate spines contain either four or five spines, proximally. The jaws bear in some cases two pairs of unequal epioral spines; in others three pairs; or sometimes two on one half and three on the other in the same individual. The interradial areas are unusually narrow, and have

fifteen to twenty small, round pseudopaxillæ, with rather long spinules. Otherwise the characters are as in the type.

A dry, thirteen-rayed specimen, in poor condition, from Esquimault Harbor, has unusually small dorsal pseudopaxillæ, so crowded that when the regularly stellate spinules are expanded the adjacent stars touch each other by their edges, or interlock, over most of the surface.

A fifteen-rayed young specimen (radii, 47 mm. and 18 mm.) from Vancouver Island (see fig.) has four of the contiguous rays on one side shorter than the rest, the two intermediate equal ones shorter than the next on each side, which are also nearly equal, thus giving the specimen a bilateral symmetry. The oral spines are four on each jaw, rather stout, nearly equal; epiorals two to four, also rather stout; laterals small, slender, graded, about six on each side. Actinal interradial pseudopaxillæ are few and very small. Adambulacral groove-spines about three in middle of rays, rather strong, often four proximally; comb-spines about four, subequal. Dorsal pseudopaxillæ very numerous, small, nearly even, circular; those on the rays very small and crowded distally.

A somewhat smaller thirteen-rayed specimen (radii, 42 mm. and 16 mm.), from the same locality, agrees well with the last in the dorsal and actinal paxillæ, but has relatively smaller and more slender adambulacral and oral spines. The apical jaw-spines are mostly six on each jaw, small and slender.

This species has a wide range, especially from Monterey Bay, California, to the Aleutian Islands. It is common in the waters of Puget Sound and British Columbia. I have studied specimens, sent by the Canadian Geological Survey, from Virago Sound; Queen Charlotte Islands; Powell Island, Gulf of Georgia (G. M. Dawson). Esquimault Bay (C. F. Newcombe). Vancouver Island; Departure Bay (Geological Survey of Canada); and from other localities.

Whiteaves (1886) recorded it from Powell Island, Malaspina Inlet, and Galatos Channel (abundant at low tide).

Fisher records it from many localities from Monterey Bay to the Aleutian Islands, from low tide to 123 fathoms. He also records it from more northern localities; but some, if not most, of these localities refer to *S. dawsoni arctica* Verrill, perhaps a distinct species, which he did not distinguish.

His more northern localities include the Kuril Islands (229 fathoms); Shumagins; and Point Franklin, on the Arctic Ocean. The latter is the type-locality of S. *dawsoni arctica* Verrill.

SOLASTER DAWSONI ARCTICA Verrill, subsp. nov.

Plate LXXXVII, figures 6, 6*a* (details); text-figure No. 14.

This subspecies is very similar in general appearance to *S. endeca* and *S. dawsoni*. Its dorsal pseudopaxillæ are rather larger than in the former and are flat-topped. The larger dorsal ones, on the disk and bases of the rays, are covered with twenty to thirty, or more, small, short, very slender, thorny spinules, of which about fifteen to twenty-five are marginal, the rest central; all are short, rising to about the same height, but the central ones may be a little shorter, in some cases. Papulæ are small and stand singly.

The adambulacral plates bear two rather long and slender, nearly equal, furrow-spines, sometimes with a smaller supplementary one,

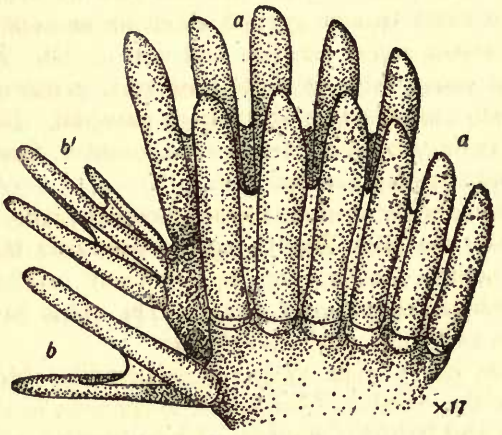

FIG. 14.

Solaster dawsoni arctica Ver., type, Arctic O. U. S. Nat. Mus. Two adambulacral plates and their spines; *a*, *a*, outer or actinal combs; *b*, *b'*, inner or furrow groups. × 17.

and a transverse comb of about five or six somewhat shorter and stouter spines, not very diverse in length, so that their tips lie in a slightly convex line. The furrow-spines rise to about the same height.

The inferomarginals are relatively rather large and prominent, strongly compressed, transversely oblong, covered with a great number of minute, rough spinules, in three or four transverse rows. The superomarginals are small, but distinct, not half as large as the lower ones, but twice as large as the dorso-laterals, spinulated like the lower ones.

Peractinals are small and inconspicuous, except proximally. The oral plates have about six or seven graded spines on each end, besides

four stout apical ones. Epioral spines numerous, six to eight in each cluster.

Radii of the type are 20 mm. and 55 mm.; ratio, 2 : 2.75; rays ten.

Northern Alaska. The type is from near Point Franklin, Arctic Ocean, in 13½ fathoms (coll. Murdoch, Point Barrow Expedition, U. S. Nat. Mus., No. 7624).

This form, which may prove to be a distinct species, is easily distinguished from typical *S. dawsoni* by the much finer and more numerous spinules of the dorsal pseudopaxillæ. They are only about half as large, but nearly twice as numerous. The less projecting adambulacral combs, the general presence of only two nearly equal furrow-spines, and other less notable characters also serve to distinguish it.

Professor Fisher records a specimen, from the same locality, as *S. dawsoni,* which may be identical with this. The locality is far more northern and arctic than any known for the true *dawsoni.* My material is not sufficient for a positive decision as to its specific distinctness.

It is certainly more closely related to *S. dawsoni* than to *S. endeca,* though the latter is the common species of the arctic coasts, while *S. dawsoni* is common from the Aleutian Islands southward to California.

SOLASTER STIMPSONI Verrill.

Plate X, figures 1, 2; plate XI, figures 1, 2; plate XV, figures 1, 2; plate XLVI, figures 1-1*c* (details); plate XCIV, figure 2 (type); plate XCV (type).

? Asterias decemradiatus BRANDT, Prod., p. 271, 1835 (no description).

Solaster stimpsoni VERRILL, in Whiteaves, Invert. of Queen Charlotte Is., Rep. Prog. Geol. Survey Canada, for 1878-79, p. 3; Whiteaves, Trans. Royal Soc. Canada, IV, p. 116, 1887. Fisher, op. cit., 1911*b*, p. 311, pl. LXXXII, fig. 3; pl. LXXXIII, figs. 1-5.

? Solaster decemradiatus STIMPSON, Journ. Boston Soc. Nat. Hist., VI, p. 89, 1857 (no description).

Solaster vancouverensis DE LORIOL, Mém. Soc. Phys. Genève, XXXII, part 2, No. 9 [p. 12], pl. 1, [XVI], fig. 5, 1896.

Disk of moderate width; rays elongated, usually ten, sometimes nine. One of the type specimens has the radii of the disk 30 mm.; of the different rays, 100 mm. to 115 mm.; ratios, usually about 1 : 3.75-4.

The rays are long, rounded above, regularly tapered, upper surface thickly covered with pseudopaxillæ composed of stellate clusters of small, blunt, strongly divergent, webbed spinules, the larger ones, on the rays, having usually five to eight spinules around the edge

and one or two in the middle of the star; on the disk, where they are more crowded, they may have six to ten radial spinules, with two or three central ones. In the smaller specimens there are fewer spinules in the clusters. These spinules are decidedly larger, stouter, more obtuse and less numerous than in *S. endeca,* and form larger pseudopaxillæ. On the lower side, the interradial spaces are smaller than in *S. endeca,* with fewer and smaller ossicles, which are roundish. Each bears a stellate group, usually with four or five tapering spinules around the edge and one or two central ones. They are rather larger than those of the dorsal surface, and much stouter and fewer than the corresponding spinules of *S. endeca.*

The inferomarginal plates are smaller and less prominent than in *S. endeca.* Each bears a transverse group of about twelve to sixteen spinules, mostly in two rows, similar to those of the sides and under surface of the rays.

Each adambulacral plate bears, on its inner edge, two small, short, tapered, acute spines, rarely three proximally, which form a longitudinal row; and on the actinal surface of each, a simple transverse row of about six to eight longer and larger, subequal, tapered spines, with subacute tips, the inner one a little larger. These are shorter, less unequal, stouter and less acute than those of *S. endeca.* The jaws bear six strong and rather long peroral spines, the two middle ones longest, the others graded; and about six smaller graded spines on each side.

VARIATIONS.

The largest specimen that I have seen is from Victoria (coll. C. F. Newcombe, Prov. Mus. B. C.). Its radii are 42 mm. to 45 mm. and 180 mm. to 190 mm.; ratios, about 1 : 4.25.

The ten rays are long, the distal part slender. It has been stained (to imitate the natural colors) bright orange, with a central star and a median band on each ray of dark purple. The dorsal, stellate pseudopaxillæ are larger than in the type, and not so closely crowded. The larger ones (pl. XLVI, fig. 1*a*) mostly bear five divergent webbed spinules around the edge and one in the middle, making a rather large, but short, regularly star-shaped group. They stand in pretty regular obliquely transverse, alternating rows on the sides of the rays, and in longitudinal rows on the dorsal side; also in regular quincunx order in many places on the sides. The papulæ mostly stand singly, but often two or three stand together, especially on the disk.

The madreporic plate is large and has four pseudopaxillæ on its surface, and others irregularly placed at its margin.

The adambulacral spines in the furrow-series are short, and stand mostly three to a plate, the middle one longest; but at about the distal fourth of the rays they are reduced to two. The actinal transverse combs consist proximally of about eight to ten webbed and feebly graded spines, in a simple, slightly curved row, the inner ones slightly longer and larger than the middle ones; but, owing to the convex summit of the plate, the middle spines are often more prominent and the tips form a curved outline; the outer ones are much shorter.

The inferomarginal plates are transversely oblong and often compressed. Each bears a marginal, webbed series of about eight to ten rather strong spinules on each side, and often a partial median row of two to four spinules.

The superomarginal plates are small, rounded or ovate, close to the inferomarginals, and bear a stellate group usually of five to seven spinules, like those of the dorsal surface.

The actinal interradial areas are relatively small and narrow, and are covered by small, rounded, unequal pseudopaxillæ, which form about eight radial rows distally. They mostly bear four to six, rarely eight, stout spinules in a stellate, webbed group, rarely with a central one. Their spinules are like those of the adjacent inferomarginal plates, but fewer.

The peroral spines consist of a terminal group of six stout, close, graded, subacute spines, with three or four much smaller spines on each side. The epiorals consist of two opposed curved and convergent rows of seven to nine graded spines, often with the opposed tips in contact or interlocking, the two inner ones decidedly stouter.

Pedicellariæ of minute size occur in this species. They were first observed by A. H. Verrill, while drawing the details of the dorsal pseudopaxillæ mounted for the microscope. They are very small, sessile around the papular pores, bivalve, often with the valves unequal. (See pl. XLVI, fig. 1c.) They are scarcely visible to the naked eye and occur only in small numbers, so far as observed, and are, therefore, likely to be overlooked. Some specimens seem to lack them entirely.

This species has a wide range, from Oregon to the Aleutian Islands, and, according to Fisher, has been taken also farther north, at Bering Island, Commander Islands group.

Dr. Fisher records it from low tide to 33 fathoms, and from Oregon to Bering Island.

It is especially characteristic of the region from Puget Sound to southern Alaska, at low tide and in shallow water. I have received numerous good specimens from the Canadian Geological Survey, taken at Departure Bay, Vancouver Island, etc. Also, from C. F. Newcombe, specimens from off Victoria, Vancouver Island (large). The type was from Ramsay Island, British Columbia (Canadian Geological Survey).

SOLASTER CONSTELLATUS Verrill.

Plate XLVI, figures 3, 4 (type); plate XC, figure 2 (type); plate XCIII (type); plate XCIV, figure 1 (type).

Solaster constellatus VERRILL, Amer. Journ. Sci., XXVIII, p. 60, figs. 3, 4, 1909. Fisher, op. cit., 1911*b*, p. 311, foot-note.

The type is eight-rayed, with a small disk and long, tapered arms. Radii of the type are 21 mm. and 78 mm.; ratio, 1 : 3.7.

The dorsal pseudopaxillæ are unusually large and elevated, regular and flower-like. They are stellate in form, and usually, where largest on the disk and base of rays, they have a single central spinule and about six equally spaced and webbed marginal spinules, which are often fully expanded and nearly horizontal, producing the appearance of a six-petaled flower. The largest ones may have six to eight divergent spines, and the small distal ones only four or five. The superomarginal and interactinal ones are quite similar to the dorsals. The peractinals are small.

The dorsal papulæ are small and mostly stout, and stand singly around the pseudopaxillæ. The latter are very regularly arranged in oblique alternating rows on the sides of the rays, or in quincunx.

The inferomarginal plates are small, roundish, and bear a small number (eight to twelve) of elongated, webbed spinules similar to the dorsal ones, but longer.

The adambulacral spines consist of a furrow-series with two, or sometimes three, short, tapered spines, and an outer comb of six to eight nearly equal, tapered spines, webbed nearly to the tips; the inner ones are usually rather longer, so that the rows are a little graded. Adoral spines are strongly graded, about ten to a jaw, the apical ones unusually stout. The superomarginal pseudopaxillæ are but little larger than the dorsal ones, but are distinct, partly owing to their greater elevation.

This is not the only eight-rayed species known to me from that coast. Its large and beautifully stellate dorsal pseudopaxillæ are distinctive and decidedly larger and with longer spinules than in

S. stimpsoni Verrill, which it somewhat resembles in certain respects. The latter is also sometimes eight-rayed.

The type is from Puget Sound (Prof. T. Kincaid, University of Washington).

Fisher (1911*b*, p. 311) suggests that this is merely an individual eight-rayed variation of *S. stimpsoni*. The species was not based on the eight-rayed condition, for no one knows better than the writer the variability of species of *Solaster* in that respect. Perhaps no one has collected and studied more specimens of the genus. This may be but a variety of *stimpsoni,* but among large numbers of the latter studied, from the same region, no intermediate specimens have been found. The most notable difference is in the larger size of the stellate pseudopaxillæ, with their few, long, slender, divergent, webbed spinules.

SOLASTER PAXILLATUS Sladen.

Solaster paxillatus SLADEN, Voy. Challenger, XXX, p. 452, pl. LXXI, figs. 1-3; pl. LXXII, figs. 1, 2, 1889. Fisher, op. cit., 1911*b*, p. 315, pl. LXXXVII, figs. 1, 2; pl. LXXXVIII; pl. LXXXIX, figs. 1, 2; pl. CXIII, fig. 3.

Rays eight to ten. Disk of rather large size. Radii, 58 mm. and 117 mm.; ratios, about 1 : 3, sometimes up to 1 : 3.7.

Dorsal pseudopaxillæ are numerous, rather close, subtabulate, a little convex; their spinules are numerous and short, thickly webbed together, about thirty to forty on the larger plates.

Marginal plates prominent, alternate, very unequal in size, upper ones about as large as dorsal paxillæ. Inferomarginals compressed, fan-shaped, with thirty to forty spinules. They form a prominent border to the rays.

Adambulacral plates with three or four long spines in the furrow-series. Actinal series in fans of five to eight proximally, long, tapered, acute, standing in a curved line, the inner end turned aborally.

Dr. Fisher records this species from seven stations, from Bering Sea to Kadiak, Alaska, in 5 to 276 fathoms. The type was from off Yokohama, Japan, in 344 fathoms.

The above description is condensed from Fisher.

Genus **Crossaster** (Müller and Troschel) restr. Verrill.

Crossaster (*pars*) MÜLLER and TROSCHEL, op. cit., 1840*a*, p. 103.

Solaster (*pars*) FORBES, Mem. Wern. Soc., VIII, p. 129, 1839; Brit. Starfishes, p. 112, 1841. Müller and Troschel, Syst. Aster., p. 26, 127, pl. III, figs. 1, *a-b*, 1842. Fisher, op. cit., 1911*b*, pp. 306, 320.

Crossaster VERRILL, Proc. Boston Soc., x, pp. 345, 356, 1866 (here first restricted). A. Agassiz, N. American Starfishes, p. 98, pl. XII (structure), 1877. Duncan and Sladen, op. cit., p. 36, 1881. Sladen, Voy. Challenger, XXX, p. 444, 1889.

Solaster (*pars*) DANIELSSEN and KOREN, p. 48, pl. IX, 1884.

Rays variable in number, usually ten to twelve. Dorsal skeleton feebly developed, flexible, the ossicles slender and openly reticulated, leaving numerous rather large papular areas. The dorsal and marginal plates bear elongated pseudopaxillæ, with numerous slender spinules clustered in the form of a brush or pencil, the middle ones longest. Superomarginals feebly developed; inferomarginals much larger, with large pencils of spinules; actinal plates few, sometimes lacking. Adambulacral spines form a regular furrow-series, usually three to five to a plate, and an exterior transverse comb of longer, webbed spines.

The dorsal ossicles do not form definite, oblique, transverse rows on the sides of the rays, as they do in *Solaster*.

CROSSASTER PAPPOSUS (Linné) Müller and Troschel.

Plate V, figure 2; plate VIII, figures 1, 2; plate IX, figure 4; plate XLIX, figure 4.

Asterias papposa LINNÉ, Syst. Nat., ed. XII, p. 1098, 1767. Walch, p. 76, 1774. O. F. Müller, op. cit., p. 234, 1776. Fabricius, Fauna Groenlandica, p. 369, 1780.

Solaster papposus FORBES, Mem. Wern. Soc., VIII, p. 121, 1839; Brit. Starfishes, p. 112, fig., 1841. Stimpson, Invert. Grand Manan, p. 15, 1853. Müller and Troschel, Syst., p. 26, 1842. Lütken, Oversigt over Grönlands Echinodermata, p. 40, 1857. Perrier, Stellérides du Mus., Arch. Zool. Expér., p. 94. Viguier, Squelette des Stell., op. cit., p. 124, 1878. Danielssen and Koren, op. cit., p. 48, pl. IX, fig. 12, 1884. Fisher, op. cit., 1911*b*, p. 325, pl. XCIV, figs. 1-6.

Solaster (*Polyaster*) *papposus* GRAY, op. cit., p. 183, 1840; Synopsis, p. 5, 1866.

Crossaster papposus MÜLLER and TROSCHEL, Wieg. Arch., IV, part 1, p. 183, 1840. Verrill, Proc. Boston Soc. Nat. Hist., X, p. 345, 1866. A. Agassiz, North Amer. Starfishes, pp. 99, 112, pl. XII, figs. 1-5, 1877. Bush, op. cit., p. 246, 1883. Verrill, Expl. Albatross, Rep. U. S. Fish Comm. for 1883, p. 541, 1885. Murdoch, op. cit., p. 159, 1885. Fewkes, op. cit., p. 63, fig., 1891. Duncan and Sladen, op. cit., p. 36, pl. III, figs. 1-4, 1881. Sladen, Voy. Challenger, Zoöl., XXX, p. 444, 1889. Ganong, Echinod. New Brunswick, p. 31, fig., 1898. Verrill, Amer. Journ. Sci., XLIX, p. 201, 1895 (distribution). Perrier, op. cit., p. 40, 1896.

Crossaster papposus DÖDERLEIN, op. cit., p. 338, 1899. Ludwig, Fauna Arctica, I, p. 460, 1900 (synonymy and distribution).

Asterias affinis and *? Asterias alboverrucosa* BRANDT, Prod. Descr. Anim., p. 271, 1835 (young, described from colored figures).

A typical Atlantic specimen, of medium size, has the radii 30 mm. and 55 mm., but the proportions vary considerably. Rays thirteen, tapered, acute. The whole upper surface is covered with rather large, unequal, elevated, spaced pencils or conical tufts of slender, elongated spinules, more or less divergent, pointed, forming rather high pseudopaxillæ. Superomarginal plates small, not easily distinguishable; lower ones larger, well defined, spaced, bearing large tufts of spinules. Actinal spinules mostly lacking. Furrow-series of adambulacral spines consists of four or five slender subequal spines on each plate. The transverse comb has six or seven longer, slender, acute spines. The four apical adoral spines are long and pretty stout; they are flanked on each side by about six slender graded spines.

In life this is a very beautiful species. The color in life is usually light red or pale orange, with the tips of the rays bright red; under side, light yellow. It sometimes becomes nearly a foot in diameter.

The Pacific specimen figured (pl. VIII, figs. 1, 2; pl. IX, fig. 4) was taken in Berg Bay, at 10 fathoms, June 10, 1899 (W. R. Coe, Harriman Expedition). According to Dr. Coe's notes it was, in life: " Pale yellow, with a horseshoe-shaped red spot on the middle of the disk, and several small pale pink spots on the rays."

Its radii are 16 mm. and 30 mm., in alcohol. In all essential characters it agrees well with the Atlantic specimens of similar size. It has the tufts of spinules of the pseudopaxillæ on the dorsal surface expanded and mostly divergent, so that the tufts appear broader and more stellate than in dry specimens. The papulæ are small, rather numerous, mostly standing singly, or two together, on the wide papular areas, around the pseudopaxillæ.

This species varies much in appearance, according to the mode of preservation. Owing to the feeble skeleton, it is apt to become flaccid and soft in drying, while the dorsal spinules may droop to one side, or collapse, so as to give very unnatural appearances. The number of rays varies from nine to fourteen, but they are usually ten to twelve.

This species is circumpolar and has a very extensive geographical range. It extends southward on the European coasts to Scandinavia, Ireland, Great Britain, and France. It is known from Greenland, Iceland, Spitzbergen, Barents Sea, East Siberia, etc. It extends southward to Cape Cod, and beyond, in deep water, on the American side. It is not uncommon in the Bay of Fundy on the shore, on stony or nullipore bottoms, at very low tides, where I have often taken

fine specimens; but it is more common in 10 to 50 fathoms or more. Large specimens are often taken on the Newfoundland Banks and the fishing banks, off Nova Scotia, by the fishermen, in 40 to 100 fathoms, on their deep-sea lines. It was taken by the U. S. Fish Commission, at many stations, in 5 to 179 fathoms, mostly on hard bottoms, from Newfoundland Banks to off Cape Cod.

On the Pacific side it occurs from the Arctic Ocean south to Vancouver Island, in shallow water; and on the coast of Siberia.

I have examined specimens from many localities: Bering Island, eleven-rayed (N. Grebnitsky); Point Franklin (Murdoch), No. 7626; and Cape Prince of Wales (W. H. Dall), No. 6059, U. S. National Museum; near Victoria, British Columbia, one, nine-rayed; one, ten-rayed; one, eleven-rayed (Prov. Mus. B. C.); Berg Bay, eleven-rayed (W. R. Coe); Puget Sound (Mus. Comp. Zoöl.); several, good; Vancouver Island (Professor J. Macoun, Canadian Geological Survey, 1909), many good.

Dr. Fisher records it from certain localities, from Bering Strait to Washington, and from low tide to 283 fathoms; but mostly in from 5 to 50 fathoms, on hard bottoms.

Asterias affinis and *A. alboverrucosa* Brandt were probably identical with this species of *Crossaster,* but the descriptions were very brief and imperfect, having been based entirely on figures of young specimens. Both were one inch in diameter of disk; length of rays, seven lines. Both were described as having ten rays, with large, scattered clusters of dorsal spinules ("papillæ"), and as resembling *A. papposa.* The number of rays cannot be regarded as a specific character. From the descriptions, both might, without hesitation, be referred to *C. papposus,* which is the form found in the same region, Bering Sea, where his supposed species were found, and where no other similar species has been obtained by modern collectors.

The *Crossaster affinis* Danielssen and Koren,[1] from the North Atlantic (*C. koreni* Verrill), is not to be considered the same as Brandt's *affinis,* which appears to be an ordinary ten-rayed *papposus,* the difference in the number of rays being the only difference given,

[1] This is referred to *C. papposus* by Ludwig and others, but the differences, as described and figured by Danielssen and Koren (1884, pp. 44-47, pl. IX, figs. 7, 8, 14), seem to be of specific value—notably the shorter and closer dorsal paxillæ; the increased number and shorter adambulacral spines; the larger actinal interradial areas, with larger ossicles; and the trifid odontophore. As it seems to have had no tenable name, I would propose for it **C. KORENI.** It has not been found on the Atlantic coast of America.

and this is also a common number of rays in the common Atlantic *papposus*.

Ludwig (Fauna Arctica, p. 464) identified Brandt's *alboverrucosa* with *S. endeca;* but Brandt recorded the latter (var. *decemradiata*) as from Sitka, in the same article. His descriptions are, of themselves, wholly insufficient to identify any species, and probably the colored drawings on which they were based were neither accurate nor detailed. It is possible that the names on the original drawings have been transposed since Brandt named them in 1835.

A closely related species (*S. penicillatus* Sladen) occurs in the South Atlantic, S. lat. 37° 25′ 30″ to 46° 43′, in 110 to 140 fathoms.

Family *ASTERINIDÆ* Gray.

Asterinidæ Gray, Ann. and Mag. N. Hist., vi, p. 228, 1840; Synopsis, p. 15, 1866. Perrier, Révis. Stell., iv, p. 292, 1875; v, p. 209, 1876. Viguier, Squelette des Stell., Arch. Zool. Expér., vii, p. 205, pl. xiv, figs. 1-13, 1878 (structure). Sladen, Voy. Challenger, xxx, p. 374, 1889. Perrier, Expl. Trav. et Talism., pp. 141, 163, 1894. Fisher, op. cit., 1911*b*, p. 253 (table of genera). Verrill, Revision of the Genera, Amer. Journ. Science, xxxv, p. 477, May, 1813.

Body usually rather flat, often thin, normally pentagonal or hexagonal, rarely with eight rays; edges usually thin, formed mainly by the inferomarginals; marginal plates small, usually scarcely larger than the adjacent dorsals, covered with a group of spinules. Dorsal plates usually flat and more or less imbricated, sometimes not imbricated; generally covered with granules or minute spinules, not rarely with tufts or combs of spines; sometimes covered with a soft, naked, or granular dermis. Under side flat; actinal plates imbricated or closely united, usually furnished with small combs or tufts of spinules, or with only one. Adambulacral spines generally webbed; furrow-spines form a comb of two to six or more, sometimes two or more combs superimposed. Pedicellariæ usually lacking; when present erect, two-bladed.

Genus **Asterina** Nardo.

Type, *A. minuta* Nardo = *A. gibbosa* (Penn.).

Asterina Nardo, Oken's Isis, p. 716, 1834. Gray, Ann. and Mag. Nat. Hist., vi, p. 286, 1840; Synopsis, p. 16, 1866. Perrier, Révis. Stell., Arch. Zool. Expér. et Gén., v, p. 214, 1876. A. Agassiz, North American Starfishes, p. 106, pl. xiv, 1877 (structure). Viguier, op. cit., vii, p. 207, pl. xiv, figs. 8-13, 1878 (structure). Sladen (*pars*), Voy. Challenger, xxx, p. 388, 1889. Fisher (*pars*), op. cit., 1911*b*, p. 254.

Ctenaster L. AGASSIZ, Prod., p. 192, 1835 (type, *C. minutus*).
Asteriscus (*pars*) MÜLLER and TROSCHEL, 1840, p. 104; Syst. Aster., p. 39, 1842.
Asterina (*restricted*) VERRILL, Amer. Journ. Science, xxxv, May, 1913, p. 481.

The genus *Asterina* should be restricted to those species closely allied to *A. gibbosa* (Penn.) of southern Europe, the type. The writer has proposed several new generic groups for the diverse species usually referred to *Asterina*.[1] The only species found on the northwest coast belongs to the restricted genus *Patiria*. Other genera are found farther south, and may occur off San Diego.

[1] The classification adopted (op. cit., 1913) for those genera most nearly allied to *Asterina* is as follows:

A. Disk and rays depressed, margins thin, the plates small.

BB. Principal dorsal plates all imbricated.

C. Ventral or interactinal plates bear a fan of two to eight, usually webbed spines.

D. Dorsal plates of papular areas spinulated, nearly all of one kind, without large groups of small intervening ossicles.

E. Two-bladed pedicellariæ are present on dorsal plates. *Asterina* Nardo (restricted). Type, *A. gibbosa* (Penn.). Europe.

EE. Pedicellariæ are lacking. *Asterinides* Verrill. Type, *A. folium* (Lutk.). W. Indies; Bermuda; Florida.

DD. Dorsal plates of papular areas are mostly lobed and notched, with a curved or lunate crest bearing fine spinules; between them are clusters of many very small spinulated ossicles.

F. Pedicellariæ are lacking. *Patiria* Gray, 1840. Type, *P. coccinea* Gray. S. Africa (monotypic). Not *Patiria* of Perrier nor of Sladen.

FF. Pedicellariæ are present on the dorsal plates. Papular areas differentiated. *Enoplopatiria* Verrill. Type, *E. marginata* (Hupé) = *E. brasiliensis* (Lütk.). Brazil; W. Indies; W. Africa.

CC. Ventral plates are without fans of spines.

G. Ventral plates have a single spine; sometimes two. Dorsal plates nearly as in *Patiria*. *Patiriella* Verrill. Type, *P. regularis* Ver. New Zealand.

GG. Ventral plates have a fascicle or cluster of spines.

H. Ventral plates have a fascicle of slender spines. *Asterinopsis* Verrill. Type, *A. penicillaris* (Lam.). Indian and Pacific Oceans; Australia.

HH. Ventral plates have a central cluster of many short spinules or granules; rays longer; rounded. *Callopatiria* Verrill. Type, *C. bellula* Sla.

BB. Principal dorsal plates finely spinulated, not all imbricated; thin, transversely elongated, with many small intervening ossicles. Plates rest on an alveolar structure, tubular interradially distally. Ventral plates, toward mouth, have an irregular group of webbed spines; distally changing to a regular comb of about three. *Desmopatiria* Verrill. Type, *D. flexilis* Ver. Chile (?).

AA. Disk and rays not much depressed; rays longer, rounded; margins not thin and subacute; larger dorsal plates not all imbricated. Here are placed *Parapatiria* Fisher. Type, *P. crassa* (Gray). *Allopatiria* Verrill. Type, *A. ocellifera* (Gray).

Genus **Patiria** Gray.

Type, *P. coccinea* Gray, 1840.

Patiria GRAY, 1840; Gray (*pars*), op. cit., 1866, p. 16 (not of Perrier, nor of Sladen).

Asterina (*pars*) PERRIER, SLADEN, FISHER, and others.

Patiria VERRILL, op. cit., 1867; Amer. Journ. Sci., vol. XXXV, pp. 480, 482, May, 1813.

Disk broad, usually pentagonal, sometimes hexagonal, depressed, with thin margins and short rays. Dorsal plates unequal, spinulated, more or less imbricated, the larger ones crescent-shaped, with the exposed edges rounded, becoming small distally; between these are many much smaller rounded ones. Marginal plates small, scarcely larger than the adjacent dorsals, upper ones usually somewhat smaller; both with marginal spinelets. Papulæ are distributed over most of the upper surface of the rays and central part of disk in radial rows. Interactinal plates have spines in small combs, often webbed. The larger dorsal ossicles have three or four internal lobes, by which they are connected together. The distal interradial plates have internal, conical, descending processes which join projections from the ventral plates.

Adambulacral plates have a furrow-comb of about three to five webbed spines, and a group of two to five spines, in a row.

Madreporic plate large, dorsal, much nearer to the center than the margin.

PATIRIA MINIATA (Brandt) Verrill.

Plate VII, figures 1, 2; plate CVIII, figures 1, 2 (varieties).

Asterias miniata BRANDT, Prodromus, p. 68, 1835.

Asteriscus miniatus STIMPSON, op. cit., VI, p. 90, 1857.

Patiria miniata VERRILL, Trans. Conn. Acad., I, pp. 234, 236, 1867 (distribution); Amer. Journ. Sci., vol. XXXV, p. 482, 1913.

Asterina miniata SLADEN, op. cit., p. 774, 1889. Verrill, American Naturalist, XLIII, p. 547, fig. 2 (six-rayed), September, 1909. Fisher, op. cit., 1911*b*, p. 254, pl. LVI, figs. 6, 8; pl. LXI, figs. 1-4; pl. LXII, figs. 1, 2.

Size large; disk rather thick; rays normally five, often six, triangular, rapidly tapered, about as broad as long. Radii of a large five-rayed specimen, 46 mm. and 92 mm.; ratio, 1:2. A large six-rayed specimen has the radii 44 mm. and 85 mm.; ratio, 1:1.93. The disk is convex or swollen, in well preserved specimens, along the radial areas, but usually with depressions between, in large specimens.

The larger dorsal plates along the median radial areas of the disk and rays are prominent, crescent-shaped, covered with short, rough

spinules. Alternating irregularly with these are many small oblong and rounded plates, similarly granulated. Everywhere in the depressed areas between the larger plates there are many lower and much smaller ossicles, unequal in size and form, bearing small clusters of small granules. The larger plates form pretty regular radial rows medially on the rays, and oblique ones on their sides.

Toward the margin, the crescent-shaped plates become smaller and shorter, and near the margin of the disk all become rounded or elliptical, with a rosette of granules; while on the sides of the rays, distally, they become elliptical and oblong, closely spinulated.

The marginal edge is formed by the two regular rows of marginal plates, which are only a little larger than the adjacent dorsals, and transversely elliptical in form, as seen covered with a wreath of spinules, slightly longer than those of the dorsals. The lower marginals are slightly the larger. The rows are separated by a narrow but well defined groove. The actinal plates form large triangular areas. They are closely arranged in many alternate rows. Each bears a group of three to five erect, slightly divergent, partly webbed spines, which become much longer and larger adorally.

The adoral spines are stout and obtuse, about three or four pairs. The epiorals are larger, stout, blunt, connivent, often only one pair on small specimens, and then they resemble spiniform pedicellariæ. On larger specimens there may be four to six connivent pairs, and then they resemble pectinate pedicellariæ.

The adambulacral plates bear a furrow-series of two or three slender, parallel, partly webbed spines and two or three larger, longer, erect, blunt spines on the actinal side.

The interactinal plates are covered with a thin skin that forms delicate, narrow, ciliated canals, transverse to the rays, and running out from between the adambulacral groups of spines.

Color, in life, commonly orange, varying to scarlet, bright red, dark red or red-brown, purple, lemon-yellow, etc.; sometimes greenish or olive, or blotched with green.

Its range extends from San Diego to middle Alaska. I have studied specimens from many localities. It is abundant on the coast of California, in shallow water and between tides, on rocky shores, at Monterey and many other places. Pacific Grove (W. R. Coe), many large examples; San Luis Obispo (Prof. E. T. Nelson). Common at Vancouver Island. Numerous large specimens were collected at Departure Bay, Vancouver Island, in 1909, by Prof. John Macoun and party of the Canadian Geological Survey. Most of

these were dark purple, but some were orange. Among them were two six-rayed specimens and one very large one with seven perfectly regular rays. Fisher records it from many localities, mostly off the California coast, from low tide to 165 fathoms, and also from the Gulf of California, north of La Paz, in 33 fathoms.

VARIATIONS.

Many regular six-rayed examples occur of full size. From Pacific Grove (coll. Prof. W. R. Coe), there is also a four-rayed specimen which is quite regular, except that one ray has been broken off and not fully restored. A regular seven-rayed specimen has been received from Vancouver Island (pl. CVIII, fig. 1), Canadian Geological Survey. Its radii measure 58 mm. and 84 mm. With the latter was a regular six-rayed specimen, with the radii 48 mm. and 72 mm.

Suborder **VELATA** Perrier. (See p. 204.)

Family *PTERASTERIDÆ* Perrier.

Pterasteridæ PERRIER, op. cit., 1875.
Pterasteridæ (*pars*) SLADEN, Voy. Challenger, vol. XXX, p. XXXVII, p. 468, 1889. Fisher, op. cit., 1911*b*, p. 343.

This is one of the most peculiar groups of starfishes hitherto discovered. It shows, in general characters, a remarkably high degree of specialization not found in any other group. Most of the genera and species are from the deep sea.

Disk usually plump; rays five to eight, rarely nine; upper surface covered by a supradorsal membrane, supported by the tips of long, slender, divergent, often webbed, paxillary spinules and pierced by small concentric pores or "spiracles," often closed and invisible in preserved specimens, and usually with a larger central osculum. Beneath this membrane is a "nidamental" cavity or gonocodium, traversed by the columnar pseudopaxillæ, and containing the papulæ, which are often branched. In this cavity the eggs are retained, and also the young, till they assume the adult form and considerable size.

The dorsal skeletal ossicles are lobed or cruciform, loosely reticulated. The adambulacral spines usually form transverse webbed combs or fans; not webbed in Hymenasterinæ. Series of slender, divergent spines, more or less appressed, and attached to the under surface, or imbedded in it, and usually webbed to the adambulacral fans in Pterasterinæ, are always present. These peculiar spines, called "actino-lateral spines" by Sladen, should rather be called

retroambulacrals, or outer adambulacrals, for they are attached to the outer end of the adambulacrals. They are sometimes short and do not reach the margin, except distally, on the rays; but in *Pteraster* and some other genera their tips usually reach the margin of the disk. Between the bases of these there is usually a small slit or pore (actinal spiracle or "segmental aperture"), furnished with a calcareous valve.

Interactinal plates are lacking. Pedicellariæ have not been found. Jaws have a series of adoral spines, usually webbed. Epioral spines of large size, in one to three pairs, often without webs, stand perpendicularly to the jaw; those of one pair are sometimes specialized and partially hyaline. Ambulacral feet are large, in two to four rows, with large apical suckers.

The supradorsal membrane may be thin and translucent, with thin muscular fibers, or thick and muscular; it may contain calcareous spicules, muscular and cartilaginous fibers in the form of a network, and often abundant mucous glands. The copious mucus is phosphorescent in some cases (*Diplopteraster*).

The intestine and anal pore are well developed. Sexes are alike externally.

Subfamily *HYMENASTERINÆ* Verrill, nov.

The genera *Hymenaster* and *Cryptaster,* and their allies, should form a distinct subfamily Hymenasterinæ, differing from Pterasterinæ in lacking webbed combs of adambulacral spines and in other characters. It is a characteristic deep-sea group.

Pythonaster Sladen does not belong to this family. It has no supradorsal membrane, actinomarginal spines, nor actinal spiracles.

Subfamily *PTERASTERINÆ.*

Genus **Pteraster** Müller and Troschel.

Pteraster Müller and Troschel, Syst. Aster., p. 128, 1842. Sladen, op. cit., p. 470, 1889. Fisher, op. cit., 1911*b*, p. 344; analytical table of all known species, pp. 368-370.

Hexaster Perrier, Comptes rendus, cxii, p. 1227, 1891 (type, *H. obscurus* Perrier).

Temnaster Verrill, Proc. U. S. Nat. Mus., xvii, p. 275, 1894 (type, *T. hexactis* Verrill = *H. obscurus* Perrier).

Disk large; rays five to eight; ambulacral grooves turn up distally, more or less, reaching to the upper side of the rays.

Adambulacral spines form equal, webbed combs; retroambulacral or actinomarginal spines closely appressed, ending in a fringe or

fold. One pair of free epioral spines; these are often translucent distally. Supradorsal membrane furnished with a central contractile osculum, guarded by five groups of webbed, projecting spines. It usually contains irregular muscular fibers for its support; muscular bands usually do not form a regular network and are generally very inconspicuous externally. Usually two rows of ambulacral feet, or nearly four-rowed, by crowding, in *P. marsippus.*

PTERASTER TESSELATUS Ives.

Plate XXXII, figures 1, 2; plate LXXXVI, figures 4-4*c* (details); plate XCVII, figure 1.

Pteraster tesselatus IVES, Proc. Acad. Nat. Sci. Philadelphia, for 1888, p. 421; and 1889, p. 169. Fisher, op. cit., 1911*b*, p. 359, pl. CIV, figs. 1-5.

Pteraster reticulatus VERRILL, op. cit., 1909*b*, p. 555 (an accidental error in spelling).

A large, plump, five-rayed species, with wide, tapered, subacute rays of short or moderate length, and with high, rounded margins to the disk.

The ambulacral grooves are turned up a little at the end of the rays, so that the distal and apical plates are dorsal. Submarginal fold narrow.

Radii of the largest (dry) specimen from Puget Sound (Prof. Trevor Kincaid) are 42 mm. and 70 mm. to 75 mm.; height, 50 mm. Radii of one from off Sidney, British Columbia, are 28 mm. and 40 mm.; height, 35 mm. The alcoholic specimen figured, from the Harriman Expedition, is larger, the greater radius measuring 90 mm. or more.

The dorsal surface is covered with a strong, thick, supradorsal membrane, through which the spinules of the pseudopaxillæ usually show only as very small points, arranged in a complex reticulated pattern. But in the largest dry specimens they appear as small, more elevated, obtuse spines or tubercles, sometimes showing a stellate arrangement, but more often closely reticulated or areolate. The dorsal osculum is relatively rather small, with elevated spinose margins, the spines not very long, rather stout, the points not projecting beyond the webs.

The adambulacral fans of spines consist of about three or four outer, rather long, nearly equal, slightly tapered spines, and two much smaller inner ones, of which the innermost is only about one-fourth as long as the outer ones, and the next one is about half their length. In some large specimens these spines become clavate.

The appressed retroambulacral or "actino-marginal" spines are unusually short and stout, a little flattened and enlarged distally, and almost twice as long as the adambulacrals; but they do not reach a third of the distance to the margin in the middle of the interradial areas, so that the dorsal spinulation extends well onto the under side, making the margins thick and swollen. They end at a strong, free fold of the membrane, which only becomes marginal near the ends of the rays. The peractinal spiracles or pores are narrow slits, with narrow, elongated, somewhat crescent-shaped valves. Adoral spines form about five graded pairs, completely webbed; the terminal ones are rather stout; the distal, very slender. Epiorals large, tapered, translucent distally. The dorsal spiracles are small and numerous, but in dry specimens and some alcoholics they are invisible, owing to strong contraction.

This species is known from Bering Sea to Puget Sound. My specimens are from Yakutat (Professor Ritter) and Sitka (W. R. Coe), Harriman Expedition; Puget Sound (Professor Kincaid); off Sidney Islands, May 10, 1896 (Prov. Mus. B. C.); British Columbia (Canada Geological Survey). Mr. Ives recorded it from Marmot Island, Alaska (type locality). Fisher recorded it from Bering Sea, off Pribilof Islands; off Shumagin Islands; off Unalaska, and various other Alaskan localities, from low water to 150 fathoms; off Vancouver Island, in 238 fathoms; Straits of Fuca, 114 fathoms; near Port Townsend, 15 to 39 fathoms; etc. Some of his specimens were much larger than the one described above. He gives the radii of one specimen as 54 mm. and 88 mm.; ratio, 1 : 1.63.

PTERASTER TESSELATUS ARCUATUS Fisher.

Pteraster tesselatus arcuatus Fisher, op. cit., 1911*b*, p. 363, pl. ciii, fig. 1.

Similar to *P. tesselatus,* but arcuately pentagonal in form, with thick supradorsal membrane, without signs of reticulation; spiracula sunken in irregular creases. Radii, 32 mm. and 46 mm.; ratio, 1 : 1.44.

Color in life, above, bluish gray or dull heliotrope purple, mottled with fawn-color, with dark interradial and lighter radial areas, and dark around margins; interradial areas below, dull heliotrope purple; marginal membrane, vinaceous buff (teste Fisher).

Monterey Bay, in 46 to 56 fathoms (Fisher).

This appears to be the same as the next, grown to larger size.

PTERASTER TESSELATUS HEBES Verrill.

Plate XCVI, figures 1, 2 (type, enlarged).

Pteraster hebes VERRILL, Amer. Journ. Sci., XXVIII, p. 61, 1909.

Disk plump and relatively large, the five rays being very short and blunt, with the ambulacral grooves and plates turned upward and reflexed upon the upper surface nearly to the base of the rays, or about even with the shallow interradial angles. Radii, 22 mm. and 28 mm.; ratio, 1 : 1.28.

The central dorsal oscule is well developed, surrounded with slender, webbed, projecting spines, in five groups of eight to ten each. The dorsal surface is covered with a multitude of crowded slender spinules, which project above the marsupial membrane and give almost the appearance of velvet pile; but in some places they form more or less evident divergent stellate clusters of twelve to twenty spinules. Seen from within, these spinules are slender, 2 mm. to 3 mm. long, very divergent, supported by slender columnar paxillæ.

The ambulacral grooves are broad and shallow. The ambulacral plates are somewhat bilobed at the inner ends, and distally are somewhat imbricated. The adambulacral spines are long and slender, about five or six in a transverse row, of which the two inner ones are very small and slender, not half as long as the outer ones, of which there are three or four, about 3.5 mm. long.

The appressed actino-marginal spines are distinctly longer, about twice as stout, and blunt proximally on the ray, but distally, on the upturned part, where they are crowded, they become about equal in length to the adambulacrals and scarcely larger; those near the interradial angles are flattened and enlarged distally; the valves at the peractinal pores between their bases are very acute, small, and slender, as seen edgewise, but when removed they are acute-triangular, and curved proximally.

Departure Bay, British Columbia, 23 fathoms, mud and sand, 1908 (C. H. Young, Canadian Geological Survey). One, dry and stuffed.

The jaws and entire oral region have been destroyed by the preparator. Therefore its relations to some of the other species are uncertain. It seems to be nearest to *P. tesselatus,* of which it is probably only a variety; some of the differences are probably due to immaturity. The mode of preparation and drying may have increased the size of the disk considerably.

PTERASTER MULTISPINUS Clark.

Pteraster multispinus H. L. CLARK, Proc. Boston Soc. Nat. Hist., XXIX, No. 15, p. 326, pl. III, figs. 1, 2, 1901. Fisher, op. cit., 1911*b*, p. 359 (description copied from Clark).

The type specimen, which I have studied in the collections of Columbia University, is a small five-rayed specimen, with short, tapered, subacute rays, broader than long, with the small tips turned up a little at the ends. Radii, 18 mm. and 27 mm.; ratio, 1 : 1.5. It is probably young; it is preserved in alcohol.

Disk a little convex, covered with small, numerous, slightly projecting spinules; there is no defined margin, the borders being rounded and the dorsal membrane continuous to the under side in the interradial areas. The dorsal membrane is rather firm, with very small spiracular pores, inconspicuous except distally on the rays. Pseudopaxillæ are hour-glass shaped, rather high, bearing eight to ten, or often more, spinules. Oscular opening rather large, surrounded by five clusters of webbed spines, about six in each group, the central ones larger.

Ambulacral feet in two rows. Adambulacral fans of spines are oblique, each with five or six spines, webbed to the tips. The inner one is much the shortest; the outer three are longest. Appressed retroambulacral spines are mostly short. Therefore there is no marginal free edge with a fringe of spine-tips along the rays, such as is conspicuous in *P. militaris* and many other species, but some of the spines in the interradial areas are rather long and slender.

Peroral spines slender, six on each angle of the jaw, webbed together. Epiorals two, rather large, slightly swollen distally at the translucent part; tips acute. Peractinal or segmental pores with a narrow spiniform valve, as seen edgewise, in natural position.

(?) Puget Sound (Columbia University Expedition, 1897).

This looks very much like a young specimen of *P. tesselatus*, younger than any of the latter that I have seen. The apparent lack of numerous spiracles on the disk is due to the strong contraction of the integument in alcohol. It often occurs in *P. tesselatus* also.

PTERASTER GRACILIS (Clark) Verrill.

Retaster gracilis H. L. CLARK, Proc. Boston Soc. Nat. Hist., XXIX, p. 326, pl. III, figs. 3, 4, 1897.

Pteraster gracilis VERRILL, op. cit., 1909, p. 555. Fisher, op. cit., 1911, p. 349 (description copied from Clark).

This is a five-rayed species, of which I have studied the type at Columbia University. It has the radii about 9 mm. and 18 mm.

The rays are about as long as broad, acute, slightly turned up at tips. It is evidently young. It was preserved in alcohol.

Dorsal surface reticulated, due mainly to the slender, divergent spinules of the pseudopaxillæ. These spinules, which form stellate groups of six to twelve or more on the slender paxillæ, are long and thin. Oscular opening small, surrounded by five groups of small spines.

Adambulacral combs of spines contain four to six, most often five. Of these the inner one is very small; then three or four much longer, subequal, central ones. Retroambulacral spines longer and larger, horizontally webbed, and partly erect. The horizontal web has a free edge parallel with the ambulacral groove. Peractinal spiracles small, with a narrow valve, free laterally.

Jaws with five webbed and graded spines, the apical ones much the larger; lateral ones small and slender. Epioral spines two, large; distal half nearly transparent; base swollen, white, opaque; tips tapered, slender, acute.

Ambulacral feet in two rows.

(?) Puget Sound (Columbia University Expedition).

This may prove to be the young of *P. tesselatus,* when specimens of intermediate sizes can be studied. The smallest typical example of the latter known to me is 80 mm. in diameter. They agree in the shortness of the retroambulacral spines, which do not reach the margin of the disk in either case, but end in a raised submarginal web, parallel with the groove. The differences that exist may very likely be due to age and mode of preservation. I see no reason for referring this species to *Retaster.* The reticulating lines, mentioned by Clark, seem to me to be merely very slender, divergent paxillary spinules, not muscular, nor cartilaginous fibers. Such muscular fibers as were noticed by me were very feeble and irregular.

PTERASTER MILITARIS (Müller) Müller and Troschel.

Asterias militaris MÜLLER, Zool. Dan. Prod., p. 234, 1776. Rathke, Zool. Dan., IV, p. 14, pl. CXXXI, 1806.

Pteraster militaris MÜLLER and TROSCHEL, Syst. Aster., Suppl., p. 128, pl. VI, fig. 1, 1842. Stimpson, Invert. Grand Manan, p. 15, 1853. M. Sars, Overs. Norges Echinod., p. 48, pl. III, figs. 8, 9, pl. IV, figs. 4-6, 1861. Duncan and Sladen, op. cit., p. 46, pl. III, figs. 13-16. Danielssen and Koren, op. cit., p. 70, pl. XIII, figs. 18, 19, 1884. Verrill, Expl. by the Albatross, p. 541, pl. XIII, fig. 35, 1885; Distrib. Echinod., p. 202, 1895.

Pteraster militaris FISHER, op. cit., 1910, p. 167; op. cit., 1911*b*, p. 346, pl. XCVIII, figs. 1, 2.

This well-known Arctic and North Atlantic species has been described by Mr. Fisher from several stations off the Pacific coast,

all from northern Alaska and Bering Sea, in 41 to 344 fathoms, except one, from the Straits of Fuca, in 100 fathoms.

It is found on both coasts of the North Atlantic, in 10 to 530 fathoms. On the East American side it ranges south to Cape Cod. Common in the Bay of Fundy, in 10 to 50 fathoms. On the European side it extends south to Norway, Scotland, and England. Common in Barents Sea, Spitzbergen, Kara Sea, Greenland, etc. It is evidently circumpolar in distribution.

Some of Dr. Fisher's specimens were unusually large. He gives the radii of one as 33 mm. and 75 mm.; ratio, 1 : 2.2.

PTERASTER PULVILLUS M. Sars.

Pteraster pulvillus SARS, Overs. Norges Echinod., p. 62, pl. VI, figs. 14-16, pls. VII, VIII, 1861. Verrill, Amer. Journ. Sci., XVI, p. 371, 1878; Distrib. Echinod., p. 202, op. cit., 1895. Fisher, op. cit., 1911*b*, p. 358, pl. CII, figs. 2, 4.

Two specimens of this Arctic and North Atlantic species are described by Fisher from off Bering Island, in Bering Sea, in 72 fathoms.

On the eastern American coast it is rare. It has been taken off the coasts of New Hampshire and Maine, and in the Bay of Fundy, in 20 to 111 fathoms, and northward to the Grand Banks. It has been recorded from the Arctic Ocean, Barents Sea, Kara Sea, Spitzbergen, etc. On the European coast it ranges southward to Norway.

PTERASTER MARSIPPUS Fisher.

Pteraster marsippus FISHER, op. cit., 1910, p. 168; op. cit., 1911*b*, p. 352, pl. C, fig. 1; pl. CI, fig. 2; pl. CXV, fig. 4; pl. CXVI, fig. 1.

A large, stellate, five-rayed species. Radii, 40 mm. and 100 mm.; ratio, 1 : 2.5.

Dorsal membrane thick, smooth, without many prominent paxillary protrusions, but with a few calcareous spicular deposits. It has so few or small spiracles that they were not visible, as preserved.

Adambulacral combs, proximally, have five spines with strong web and sacculus extending beyond tips. A longitudinal, narrow web between successive combs, at the outer border.

Tube-feet crowded so as to appear to be in four rows, except in young.

Bering Sea, in 52 to 351 fathoms, southward to the Aleutian Islands.

This species, in the partially four-ranked arrangement of the tube-feet, approaches *Diplopteraster*.

PTERASTER OBSCURUS (Perrier) Döderlein.

Hexaster obscurus PERRIER, Mém. Soc. Zool. France, IV, p. 267, 1891; Rés. Camp. Sci., XI, p. 41, pl. III, figs. 1, 1*a*, 1896.
Pteraster (*Temnaster*) *hexactis* VERRILL, Proc. Nat. Mus., XVII, p. 275, 1894.
Temnaster hexactis VERRILL, Amer. Journ. Sci., XLIX, p. 202, 1895.
Hexaster obscurus VERRILL, Revision, Trans. Conn. Acad., X, p. 271, 1899.
Pteraster octaster VERRILL, Amer. Journ. Sci., XXVIII, p. 61, fig. 1, 1909 (variety).
Pteraster obscurus FISHER, op. cit., 1911*b*, p. 363, pl. CV, figs. 1-4; pl. CVI, figs. 1, 2.

The original description of *P. hexactis* was as follows:

"Disk broad, very high, evenly convex, with a rather large central opening surrounded by circles of prominent, imbricated, and webbed spines. Rays six, short, broad, tapered to blunt tips, their lateral margins convex. Lesser to greater radii, about as 1 to 1.5. Lesser radii, 22 mm.; greater radii, 32 mm. to 35 mm., in the alcoholic specimen; height of disk, 30 mm.

"The surface of the disk is covered with very numerous small spinules, covered more or less completely with a thick skin-like membrane, and arranged in irregular, divergent groups.

"The integument between the spinules is thick, smooth, firm, and everywhere perforated by numerous very small, round pores.

"In each interradial region there is a narrow, radiating groove, lined with thick naked integument, destitute both of spinules and pores, but showing a wrinkled surface. These grooves commence at about one-fourth the distance from the dorsal center to the margin. In some cases there is only a small slit-like opening in the upper end of the groove, communicating with the space beneath the dorsal membrane, but in some of the interradii the slit is much larger and longer, reaching nearly or quite to the margin, and communicates with a large marsupial pouch, containing well-formed young, some of which were in the act of escaping when preserved. Apparently the slit-like openings are formed, or at least much enlarged, when the young are ready to come forth, and after their birth the edges of the slits may become again united.

"The dorsal spines or pseudopaxillæ beneath the integument are large, stout, rather long, and surmounted with a large divergent group of long, slender spinules. In the interradial region, within the marsupial pouch, there is a group of several lobed or branched papulæ at the base of each paxilliform spine. The large spines situated along each side, within these cavities, have rudimentary spinules at the summit, which do not reach the outer membrane, so

that they stand free within the cavity, thus leaving the membrane unsupported along the slits. On the ventral side the rays are nearly flat, and the disk around the mouth is deeply concave.

" Each ray is broadest at the margin of the disk. The transverse adambulacral combs are numerous and covered with a thick, firm skin, which entirely conceals the spines in alcoholic specimens. On the broadest part of the ray, opposite the margin of the disk, there are mostly four, rarely five, spines of moderate length in each comb; of these the one next the groove is somewhat shorter than the two or three which succeed it, while the outermost is still shorter and directed more outward, so that the group has a somewhat rounded, but not very elevated, scolloped margin, the membrane receding somewhat between the points of the spines. The spines, when exposed, are rather slender, flattened, rough, and truncate at the flat tip; beyond the outer spine the web rapidly becomes less elevated and each comb lies somewhat obliquely over the one next beyond it, and becomes only a slightly elevated broad fold before reaching the margin. These folds entirely conceal the appressed, outer adambulacral spines, which extend to the margins of the rays, but project very little if at all beyond it, so that the margin is merely crenulated, or divided into small blunt lobes by slight notches. The spiracles, between the outer ends of the webbed adambulacral spines, are ovate pores, sometimes closed by an ovate operculum; but in other cases they are occupied by a small group of two or three short, papula-like organs.

" The jaws are surrounded by a marginal group of long, slender, webbed spines, of which there are about four or five on each side; the two innermost are somewhat the larger. On the actinal side of the jaws there are also two much larger, isolated epioral spines, one on each plate; these are entirely covered by a thick skin; when this is removed the spine is flattened, tapered, and blunt at the tip, with a rough surface, but not hyaline.

" Color, in alcohol, dull purple.

" The ambulacral feet are large and in two regular rows."

The specimen described above as the type of *P. hexactis* was taken off Newfoundland, in 57 fathoms, N. lat. 43° 05′. The type of *obscurus* Perrier was from the Banks of Newfoundland, in 155 meters. The few Atlantic specimens have all been six-rayed, except one seven-rayed specimen. It has also been taken at Spitzbergen and Greenland.

Professor Fisher records it from a number of localities in Bering Sea, from Bering Strait to Bering Island and Unalaska, and off Kamchatka, in 17 to 85 fathoms. I have also had six-rayed specimens from the same region.

He has found that in Bering Sea it occurs with six to nine rays, but most frequently with six rays. The only nine-rayed specimen was a young one taken from the marsupial pouch of an eight-rayed specimen. One of my eight-rayed specimens also contained a nine-rayed young one. Some of his specimens were much larger than the one described above. The largest six-rayed specimen had the radii 43 mm. and 71 mm.; ratio, 1:6.5. The largest seven-rayed one had the radii 56 mm. and 82 mm.; ratio, 1:6. His large specimens had five or six spines in the adambulacral combs, proximally. He did not find genital, interradial slits, showing that they are temporary, for the escape of the young, as suggested above.

PTERASTER OBSCURUS, var. OCTASTER Verrill.

Pteraster octaster VERRILL, Amer. Journ. Sci., XXVIII, p. 61, fig. 1, 1909. Fisher, 1911*b*, pl. CVI, fig. 1.

The Pacific form with eight or nine rays, most commonly eight, seems worthy to retain the name *octaster,* as a variety. The original description was as follows:

"Disk large and plump; margins well defined by points of the actino-marginal spines; rays eight, short, about as wide as long, subacute; the ambulacral grooves turn up but little at the tips. Radii of the largest example, 20 mm. and 30 mm.

"Dorsal surface covered with a thick membrane through which the tips of the spinules show but little as pretty uniformly scattered points; in alcohol they form the apex of small, low, conical, fleshy elevations. Central oscule small, in alcohol inconspicuous, its short spines covered by a soft membrane. Ambulacral feet large, in two rows.

"Adambulacral spines form combs of five or six spines, of which the innermost is much smaller and more slender than the rest, which are rather stout, tapered, subacute, divergent; the outer ones longer; the outermost appressed to the surface. Epioral pair of spines long and rather stout, tapered, translucent distally. The interradial areas are narrow, with rows of long, stout, imbedded actino-marginal spines, the ends of which project a little at the margin of the disk.

"Four specimens were sent to me by the U. S. National Museum. Three were from Bering Island, collected by Dr. Stejneger and Mr. N. Grebnitsky, in 1888. One was from Kamchatka, collected by N. Grebnitsky."

Dr. Fisher records the eight-rayed form from Bering Strait, 17 fathoms; Bering Island; and from the Pribilof Islands, in 26 fathoms.

He states that he has taken seven-rayed, eight-rayed, and nine-rayed young from the gonocodium of a single eight-rayed specimen; and six-rayed young from a seven-rayed specimen. This shows that the number of rays is of no great importance in this species. The young, when they leave the pouch, are from 12 mm. to 20 mm. in diameter (teste Fisher).

One of the eight-rayed specimens described by me was in the act of giving birth to a nine-rayed young one, about 12 mm. in diameter. In that specimen the interradial slits were well marked, with smooth edges (not ruptured), not only where there were young beneath, but also in the interradial areas where there were no young. The arrangement of the paxillary spines in the interradial areas, is such as to facilitate the formation of the slits. Whether there is a sexual difference in this respect, I do not know.

The species of this genus might be thought hermaphrodite, for it is rather unusual to find adult specimens that do not carry young. But Professor Fisher has dissected a large specimen of *P. jordani* which proved to be a male, not differing externally from the females. Probably the males are fewer in number than the females.

Genus **Pterasterides** Verrill.

Type, *Pteraster aporus* Ludwig.

Pterasterides Verrill, Amer. Naturalist, xliii, p. 547, September, 1909.

Differs from *Pteraster* in being destitute of a notable central dorsal oscule and in having groups of spines around the dorsal pore which do not reach the supradorsal membrane. In other characters much like *Pteraster*. Numerous young were found in the nidamental cavity by Professor Ludwig.

Professor Fisher thinks that the type was merely an abnormal *Pteraster militaris*. Ludwig mentions young taken from the nidamental cavity, but does not say that they disagreed with the mother, as would most likely have been the case if the absence of the osculum was abnormal.

PTERASTERIDES APORUS (Ludwig) Verrill.

Pteraster aporus LUDWIG, Zool. Jahrb., p. 293.
Pterasterides aporus VERRILL, Amer. Naturalist, XLIII, p. 547, 1909.

I have not seen this species. The original description follows:

"The radius of the disk is 35 mm., that of the arm, 98 mm. Where the arms branch off from the disk, the width is from 40 mm. to 42 mm. Both disk and arms are somewhat flattened. The supradorsal membrane is rather thick, soft, with corrugated (wrinkled) upper surface, through which calcareous spines in no wise protrude; in its outermost layer are found, on microscopic investigation, numerous reticulate little calcareous bodies, from the outer surface of which small pointed spinelets project. The paxillæ, which support the supradorsal membrane, consist of a pedicel (stalk) from 2 mm. to 3 mm. long, from the upper end of which, as a rule, four much thinner spines, about 5 mm. long, diverge. On the inner dorsal skin the paxillæ are inserted at intervals of 3 mm., on the average. The calcareous net of the inner dorsal skin, on the knotted points of which the paxillæ stand, is made up of more or less elongated calcareous plates, which partly overlap the knotted points of the network, like tiles. In the circumference next to the large anal opening into the nidamental cavity are some noteworthy thick paxillæ, which bear on their upper ends a great number of spines. On the under side of these starfishes one may count, on each arm, over fifty pairs of little feet and a corresponding number of fins (or combs). Towards the exterior the overlying marginal border is so wide that it reaches to the edge of the arms. All the spines of the marginal border and of the combs are enveloped for their length in a rather thick and soft membrane. In each comb lie from eight to nine spines, of which the two innermost, standing next to the ambulacral furrow, are very weak and much shorter than the six to seven outer ones, which are strong and of about equal size. Between the combs may be seen the large segmental apertures furnished with clapper-shaped aperture-papillæ. At the mouth, each jaw carries an oral comb, which bears six spines ('mouth-spines proper,' Sladen) and is not united with its neighbor. Towards the exterior from this comb, on each jaw, is a light, curved, rarely strong, single spine ('secondary mouth-spine,' Sladen) which likewise is covered by the soft skin.

"From all the species of *Pteraster* now known (*militaris* Müller and Troschel, *pulvillus* M. Sars, *multipes* M. Sars, *capensis* Gray, *cribrosus* v. Mart., *danæ* Verrill, *affinis* Smith, *rugatus* Sladen, *stellifer* Sladen, *semireticulatus* Sladen, *carribæus* Perrier), the

present unique example, of which unfortunately no previous original account exists, may be distinguished in a conspicuous manner by the absence of the so-called oscular orifice of Sladen, in the supradorsal membrane (comp. because of this and some others among the following required characters: Sladen, Asteroidea of the 'Challenger' Expedition, Preliminary Notice, Part I, Pterasteridæ; in Journ. Linn. Soc., London, XVI, p. 191, 1882). If all other characters did not correspond with those of the genus *Pteraster,* one would be warranted in founding a new genus on the above-mentioned absence of the so-called oscular orifice. As I propose to give in another place a more detailed discussion of the organization of this new species, and a description of the numerous quantity of young forms found in the nidamental cavity, I shall content myself for the present with a short account, setting forth the evident differences between this and other known species." (Ludwig.)

Bering Sea, off St. George Island, in 30 meters (Ludwig).

Genus **Diplopteraster** Verrill.

Diplopteraster Verrill, Amer. Journ. Sci., XX, p. 400, 1880. Fisher, op. cit., 1911*b*, p. 370.

Thick, pentagonal, or short-rayed, with a thick outer integument containing strong reticulated muscle bands. Marginal membranous fold wide and thick. Oral spines webbed together. Tube-feet in four rows. Fans of adambulacral spines and furrow-series alternately larger and smaller, and alternately placed farther forward and back.

In life, the surface secretes a large amount of mucus, when taken from the sea, and emits strong phosphorescent light.

When fresh the surface appears smooth or nearly so. In preserved and contracted specimens the larger paxillary spines push up against or through the dorsal membrane, so as to give it a more or less bristling or spinose appearance, as happens in most other species of Pterasteridæ.

DIPLOPTERASTER MULTIPES (Sars) Verrill.

Pteraster multipes M. Sars, Vidensk. Selskabs. Förhandl., 1865, p. 200; Fauna Litt. Norvegiæ, p. 65, pl. VIII, figs. 1-17, 1877.

Retaster ? multipes Sladen, op. cit., pp. 477, 478, 800, 1889.

Diplopteraster mulitpes Verrill, Amer. Journ. Sci., XX, p. 400, 1880; Ann. Report U. S. Fish Comm., for 1882, X, p. 659, 1884; op. cit., XI, Expl. by the Albatross in 1883, p. 542, pl. 14, fig. 43, 1885; Distrib. Echinod., op. cit., 1895, p. 202. Fisher, op. cit., 1911*b*, p. 371, pl. CVII, figs., 1, 2.

This large North Atlantic and Arctic species has been recorded from the Pacific side by Professor Fisher, from several stations in Bering Sea and off the Aleutian Islands, in 81 to 350 fathoms, and also from off San Diego, California, in 628 to 640 fathoms.

On the Atlantic side it has been found at many stations between N. lat. 44° 26′ and 37° 07′ 50″, in 70 to 640 fathoms. Most common between 100 and 300 fathoms.

It extends southward on the European coast to Norway. Also recorded from Barents Sea and off Japan. I have seen no Pacific specimens.

Although it has not been taken quite within the limits of this report, it is introduced here on account of its distribution as a circumpolar species.

When first taken from the sea I have observed that this species is highly phosphorescent. It discharges a large amount of thick mucus to which the phosphorescence seems to be due.

The integument and wide marginal fringe, when fresh, are very soft and thick.

Order **PHANEROZONA** Sladen (emended).

Phanerozona (emended) Sladen, Voyage Challenger, Zoöl., xxx, Introduction, pp. xxviii, xli, 1889. Verrill, Revision, Trans. Conn. Acad., x, p. 200, 1899. Fisher, op. cit., 1911*b*, p. 17.

Valvatæ + *Paxillosæ* (as orders) Perrier, in Mém. Etoiles de mer, Antilles etc., p. 154, 1884.

Valvata + *Paxillosa* Perrier, Expéd. Trav. et Talism., pp. 22, 23, 28, 29, 1894; Résultats Camp. Scientif. Albert I, Prince de Monaco, fasc. xi, p. 16, 1896.

This order includes starfishes varying in form from pentagonal to stellate, with long rays. They have two rows of large and thick marginal plates (rarely but one distinct row, as in *Luidia*), which are in contact and usually form a thick, nearly perpendicular margin. They are nearly always larger than the dorsal and actinal plates. Papular pores are generally confined to the upper surface and usually placed singly, often in special areas. Dorsal plates various. Their surfaces may be closely covered with angular tesselated plates, which may be naked, granulated, or covered with a smooth skin; or they may take the form of pseudopaxillæ, protopaxillæ, or true paxillæ,[1] especially in Paxillosa.

[1] The various forms of paxilliform plates were thus distinguished by me in 1894:

"True *paxillæ* are columnar or hour-glass-shaped ossicles, usually with isolated, circular bases, which bear at summit a group of small spinules, of which the marginal series are usually different from the rest and divergent, so as to cover the intervening spaces between the spines, thus forming

In some families the plates are reticulated ossicles, smooth, or bearing large spines or tubercles as in Oreasteridæ. In other cases (*Porania,* etc.) a thick skin may cover and obscure the plates.

The interactinal plates may be few in stellate forms or many in the pentagonal forms. In the latter cases they are usually arranged in definite rows, most often parallel with the adambulacral plates, the latest formed ones being situated next the median, interradial, marginal plates.

The interactinal plates are most commonly tesselated and granulated, or else in the form of pseudopaxillæ or protopaxillæ; but they are sometimes spinose. They may be more or less imbricated by their edges or lobes.

Adambulacral plates are not compressed, rather large, usually quadrangular, and commonly bear numerous small spines, various in arrangement.

Ambulacral plates are rather large, not compressed nor crowded. Ambulacral feet are in two rows, with terminal suckers in Valvulosa; but in the Paxillosa large and pointed, or without suckers.

A median, dorsal, nephridial pore or pseudanus is generally present, but often absent. Madreporic plate various. Dentary or oral plates are often large, with numerous oral spines.

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fascioles. These are highly developed in most species of *Astropecten* and *Luidia.*

"*Spinopaxillæ* are of the same general structure, but the center of the summit is occupied by a distinct spine, or by more than one. Such forms occur on *Luidia, Pontaster,* etc.

"*Parapaxillæ* are lower and broader, rounded, or stellate ossicles, or angular plates, with a raised central portion, tabulate, truncate, or like a low cone. They may be either isolated or articulated by their bases. The summit is covered with small, short, differentiated spinules, like those of true paxillæ. Those on the dorsal surface of *Plutonaster* are examples. They sometimes bear a central spine.

"*Protopaxillæ* are similar, but less elevated, convex ossicles or plates, covered with round or angular granules, with the marginal series differentiated and more or less covering the grooves between the plates. As in the preceding, there may be a central spine in some cases. This form also occurs on *Plutonaster,* and on many species of Goniasteridæ. The transition from this last kind to simple, uniformly granulated plates is easy, when the grooves between the plates become obsolete.

"*Pseudopaxillæ* are articulated plates with a flattened, usually lobed, and often overlapping base, which bear a group of slender, fascicled or divergent spinules on the more or less raised central or subcentral area or boss. These have no differentiated marginal series of spinules. This form is seen in *Solaster, Henricia,* etc."

Pedicellariæ are sometimes lacking, but usually present and sometimes large. They may be bivalvular, sessile and seated over a pore (foraminate), or implanted in special pits on the plates (fossate); or else papilliform or fasciculate, composed of two to four or more modified, convergent spinules; or pectinate, consisting of two comb-like groups of spinules convergent over a suture between two adjacent plates, as in *Luidiaster* (see pl. XXXIV).

The sessile valvular pedicellariæ with a pore between the valves are called *foraminate;* they may have two, or more than two, valves (*bivalvular* and *trivalvular,* etc.). In the suborder *Valvulosa* they are often provided with a pair of pits or fossæ, into which the valves fit when widely open. The valves in these are often spatulate, spoon-shaped, tongs-shaped, or battledore-shaped, and usually may best be called *plataleiform* or *spatulate.* When furnished with receiving pits, they have been called *excavate;* but *fossate* seems to be a more appropriate term.

The peculiar papilliform pedicellariæ of the Paxillosa, with two to four or more slender valves, apparently formed by modified spinules or granules, are also found in certain of the Valvulosa. Sometimes such pedicellariæ are found associated with larger valvular pedicellariæ on the same specimen, as in the genus *Nymphaster,* and in a few other genera.

The writer, in a revision of the classification of the Asterioidea, in 1899, proposed a rearrangement of the families and subfamilies. That general arrangement is here adopted, but with various changes made necessary by subsequent discoveries.[1]

Order **PHANEROZONA.**

Suborder I. **VALVULOSA** Verrill = **VALVATA** Perrier (sense extended).

Family I. *OPHIDIASTERIDÆ* Verrill, 1867 = *Linckiadæ* Perrier, 1875.

Family II. *VALVASTERIDÆ* Fisher, 1911.

Family III. *ASTEROPIDÆ* Fisher, 1911.

Family IV. *OREASTERIDÆ* Fisher = *Pentacerotidæ* Gray (restricted).

Family V. *MIMASTERIDÆ* Verrill.

Family VI. *GONIASTERIDÆ* Forbes (restricted), includes *Antheneidæ* Perrier (restricted).

[1] Dr. Fisher (op. cit., 1911*b*) has adopted a very similar arrangement of the families and subfamilies, with several changes, which are here mostly accepted. Some small extralimital groups are not included in this table.

Subfamily I. *GONIASTERINÆ* Verrill = *Pentagonasterinæ* Sladen (*pars*).
Subfamily II. *PSEUDARCHASTERINÆ* Sladen.
Subfamily III. *MEDIASTERINÆ* Verrill, 1899.
Subfamily IV. *NECTRIINÆ* Perrier; Fisher.
Subfamily V. *HIPPASTERIINÆ* Verrill.
Subfamily VI. *ANTHENEINÆ* Fisher (sense restricted).
Subfamily VII. *LEPTOGONASTERINÆ* Perrier.
Subfamily VIII. *CHITONASTERINÆ* Fisher.

Family VII. *ODONTASTERIDÆ* Verrill = *Gnathasterinæ* Perrier (*pars*).
Family VIII. *CHÆTASTERIDÆ* Ludwig.
Family IX. *ARCHASTERIDÆ* Verrill (restricted to *Archaster*).

Suborder II. **MYONOTA** Ludwig.

Family X. *BENTHOPECTINIDÆ* Verrill = *Benthopectininæ* Verrill, 1894.

Subfamily I. *BENTHOPECTININÆ* Verrill, 1894.
Subfamily II. *PONTASTERINÆ* Verrill, 1899.

Suborder III. **PAXILLOSA** Perrier (sense restricted).

Family XI. *PORCELLANASTERIDÆ* Sladen.

Subfamily I. *PORCELLASTERINÆ* Sladen.
Subfamily II. *CTENODISCINÆ* Sladen.

Family XII. *GONIOPECTINIDÆ* Verrill.
Family XIII. *ASTROPECTINIDÆ* Gray (restricted).
Family XIV. *LUIDIIDÆ* Verrill = *Luidiinæ* Sladen.

It will be noticed that in the above arrangement the family Archasteridiæ of Perrier, 1894, is divided among five distinct families and subfamilies. Most of his genera are now placed in the Pseudarchasterinæ.

The subordinal name *Valvata* I have here changed to Valvulosa, partly because it is not strictly identical with Valvata of Perrier, and partly to make its termination correspond with Paxillosa.

In the arrangements of Perrier, and of Sladen, *Valvaster* is made a subfamily, Valvasterinæ, of the family Echinasteridæ. Fisher

makes it a family of Spinulosa. The reasons for this are not very evident, for Valvaster has a series of large, broad, valvular pedicellariæ on the superomarginal plates, which are not otherwise found in the family Echinasteridæ, nor in the order Spinulosa. Moreover, it has erect bivalve pedicellariæ on the actinal and adambulacral plates, with large marginal plates in two rows, and is, therefore, phanerozonate. These characters and its jaws and odontophore indicate that it belongs to the suborder Valvulosa.

It should, in my opinion, form a separate family, Valvasteridæ, near Ophidiasteridæ, but peculiar in having the dorsal ossicles reticulated and bearing solitary spines in longitudinal rows. Odontophore with articulating tubercles, as in Ophidiasteridæ; jaws pointed. Actinal plates bear flattened spines. The ambulacral suckers have a rosette of calcareous deposits.

The former subfamily Mimasterinæ I have here raised to the rank of a family, to include only the genus *Mimaster,* which seems to be a rather isolated form.

The families of the above list represented within our limits are Nos. I, III, VI, VII, X, XI, XIII, XIV.

Suborder **VALVULOSA** Verrill = **VALVATA** (Perrier), emended.

Valvulatæ (order) PERRIER, Nouv. Arch. Mus. Hist. Nat., VI, 1885.
Valvata (order) PERRIER, Expéd., Trav. et Talism., pp. 22, 23, 28, 29, 1894.
Valvata (suborder) VERRILL, Revision, Trans. Conn. Acad., X, p. 200, 1899.

This extensive group includes starfishes with stellate or pentagonal forms, usually rather stiff in appearance, and nearly always five-rayed, in which the dorsal plates are most commonly tesselated and granulated, or else take on the character of protopaxillæ or pseudopaxillæ. Sometimes they are naked; often spinose; very rarely truly paxilliform; sometimes covered by a thick, smooth, or granulated integument.

The various kinds of abactinal ossicles pass into each other by various intermediate forms, so that it is impossible to draw any very strong or sharp family lines on this character alone, though the character of the plating may generally be taken as of generic value. Sometimes they are openly reticulate; rarely (Asteropidæ) they are partly abortive.

Pedicellariæ are often lacking; when present they are usually valvular, foraminate and sessile, or fossate. The valves are either granuliform, or large and broad, or narrow and spoon-shaped, plataleiform, spatulate, or battledore-shaped, rarely papilliform.

Actinal plates are usually rather numerous and tesselated or imbricated. Adambulacral spines are usually numerous and papilliform or spiniform. A distinct dorsal pore (*pseudanus*) is usually present. Genital pores generally ten, usually all separate, situated in the dorsal interradial areas; sometimes serial on the sides of the rays. Oral plates usually large and convex on the actinal surface.

Superambulacral plates are present in some genera, absent in others. The existence of superambulacral plates has formerly been supposed to be characteristic of the Astropectinidæ only, but they exist in several of the genera here referred to Valvulosa (viz., *Mediaster, Dytaster, Pseudarchaster,* etc.), and in other groups.

Adambulacral plates wide, with a longitudinal group of small furrow-spines and with one or several spines on the actinal side, often becoming much longer distally. Dentary or jaw-plates large and usually convex on the actinal surface, bearing numerous oral and epioral spines.

Ambulacral feet large, with suckers. Owing to the generally close union of the ossicles, especially of the large marginal plates, most of these starfishes are rather rigid, showing much less flexibility than in most other groups. The Ophidiasteridæ are exceptional in this respect, for they are mostly very flexible.

Family *GONIASTERIDÆ* (Forbes), emended Verrill.

Goniasteridæ (*pars*) Forbes, 1840. Verrill, Trans. Conn. Acad. Sci., I, p. 343, 1867. Perrier (*pars*), Revision, Arch. Zool. Expér. et Gén., IV, pp. 281, 283, 289, 291, 1875; op. cit., V, p. I, 1876.

Pentagonasterinæ Viguier (*pars*), subfamily, op. cit., VII, p. 166, pl. X, figs. 20-25, 1878.

Pentacerotidæ (*pars*) Gray, Synopsis, p. 5, 1866.

Pentagonasteridæ (*pars*) Perrier, op. cit., p. 231, 1884. Sladen (*pars*), op. cit., pp. 260, 264, 1889.

Goniasteridæ Verrill (restricted), Revision, in Trans. Conn. Acad. Sci., X, p. 145, 1899 (*non* Viguier). Fisher, op. cit., 1911*b*, p. 158.

Phanerozonate starfishes usually having a rather broad, flat or slightly convex, rather rigid disk, sometimes nearly pentagonal in form, but often stellate with more or less prolonged rays. Marginal plates usually large and thick, forming a thick, nearly vertical margin, the two rows equal or subequal.

Dorsal plates various, but usually tesselated, polygonal, or roundish, sometimes lobed or substellate, or united by internal ossicles. They are commonly granulated or protopaxilliform, sometimes spinulose, or bear tubercles or spines; rarely naked, or covered with soft skin, with or without granules or pedicellariæ.

Interactinal plates usually numerous, angular, tesselated, or imbricated. Superambulacral plates may be present or absent. Tube-feet are in two rows and have suckers.

Pedicellariæ usually present, often large, usually bivalve, but may be multivalved, foraminate, more often fossate. They may occur on any of the plates, or on the thick skin that covers them in some genera (*Anthenea,* etc.).

NOTE ON THE EARLY GENERIC NOMENCLATURE OF THE GONIASTERIDÆ.[1]

The name *Pentagonaster,* as used by Linck, designated a composite group of pentagonal starfishes of this family and others; but Linck was not a binomial writer. Gray, 1840, was the first binomial writer to adopt Linck's name. He restricted it to a small group, afterwards named *Stephanaster* by Ayres (type *P. pulchellus*), chiefly distinguished by the swollen distal marginal plates. To this type *Pentagonaster* must evidently be restricted.

Goniaster L. Agassiz, 1835.[2] This generic name was also intended to include all the pentagonal starfishes then known to him, that are now referred to Goniasteridæ and Oreasteridæ.

Among the species named by Agassiz was *G. tesselatus* Lam. J. E. Gray, in 1840, restricted *Goniaster* to the latter, as he had a perfect right to do, and his use of the name must be maintained. For another of the species (*equestris*), cited by Agassiz, Gray established the genus *Hippasteria,* at the same time. The first and the third species were placed by Gray in his genus *Pentaceros,* now *Oreaster* (M. and Tr.).

The species named by Agassiz (see foot note 2, this page) thus became the types of three genera in Gray's system. There is no reason, under the accepted rules of priority, for changing his application of the first two of these generic names, for his types are all well-known species.

It is possible, however, that it may eventually be thought by some desirable to unite Gray's three genera—*Goniaster* (restr.), *Pentag-*

[1] See also Verrill, Revision of Certain Genera and Species of Starfishes, etc., Trans. Conn. Acad. Sci., x, pp. 146-162 (Goniasteridæ). Fisher, W. K., Necessary Changes in the Nomenclature of Starfishes, Smithsonian Miscell. Coll., LII, 1908, pp. 91-93 (historical), and op. cit., 1911*b*, p. 163.

[2] The species of *Goniaster* cited by Agassiz (Prodromus, 1835, p. 191) are as follows: First, *G. reticulatus* (now *Oreaster*); second, *G. equestris* (now *Hippasteria phrygiana*); third, *G. nodosus* (now *Oreaster*); fourth, *G. tesselatus* (the type of *Goniaster* Gray).

onaster (restr.), and *Tosia* (restr.)—into one large genus, for they are closely related. In that case the name *Goniaster* should be applied to the entire group, under which the other two names might be retained for subgenera or sections. *Goniaster* is certainly the earliest of these names, under the binomial system.

The restriction of *Goniaster* to a species not mentioned by Agassiz (*obtusangulus* Lam.), as has been done by Perrier and by Sladen, is entirely contrary to the rules of nomenclature, and quite unjustifiable. Therefore the latter was made the type of a genus (*Pseudoreaster*) by me in 1899.

Astrogonium of Müller and Troschel, 1842, should properly have been dropped from the system long ago. It was a very heterogeneous group, composed (as the authors themselves stated), of several of Gray's genera recombined. This unnatural combination has been rejected by many subsequent writers. It is a synonym of Gray's genera.

Astrogonium was nearly equivalent to the typical Goniasterinæ, collectively.

Hippasteria. The type of the latter was the first-named species of *Astrogonium.*

Gray, 1866, endeavored to restrict *Astrogonium* to a minor group, but his first and most typical species (*granularis*) is a *Tosia,* according to Gray's definition of the latter. Others belong to very different genera.

Sladen restricted it to the group named *Pentagonaster* by Gray and *Stephanaster* by Ayres, which is contrary to the generally accepted rules of priority. Other attempts to restore it have been equally unfortunate. Perrier formerly used it for a section of *Pentagonaster.*

Goniodiscus Müller and Troschel embraced several diverse genera of Gray's system (as stated by them), such as *Paulia, Anthenea, Randasia, Nectria, Hosea.* Their first species (*pentagonulus*), presumably intended as the type, was also the type of Gray's *Anthenea.* Two of their species belong to *Tosia* Gray.

Perrier, and also Sladen, have restricted it to several species referred to *Hosea* by Gray in 1847 and 1866. The latter genus was, however, founded by Gray in 1840, with a single species (*H. flavescens* Gray) as the type. Perrier, who has studied this type, states that it is a true *Anthenea.* If this be so, *Hosea* becomes a synonym of the latter.

Gray, in his later works, referred to *Hosea* several additional species, which were described under *Goniodiscus* by Müller and Troschel.

The restriction of *Goniodiscus* to this residual group of species by Perrier, 1875, was indefensible as well as undesirable. This group of species,[1] as thus restricted, was characterized by having the abactinal radial plates "stellate," or polygonal with notched sides, and by small, narrow, forceps-like pedicellariæ, usually scarcely larger than the granules, and much like those of *Tosia*.

But if the type is a young *Culcita*, as stated by Clark, the name is obsolete. At least one species (*Anthenea granulifera* Gray), referred to *Goniodiscus* by Perrier, who described the figured type, should probably be generically separated, for it has short valvular pedicellariæ.

The above discussion was written almost exactly in its present form in 1904, and was an extension of the notes on the same subject published by the writer in 1899. (Revision of Genera and Species of Starfishes.)

Professor Fisher (1911*b*, pp. 163-169) has since discussed the same subject in much the same way. His conclusions are so closely in accord with my own that it might seem superfluous to print my results here. It is, perhaps, useful to do so, on the principle that the testimony of two is better than that of one. In this case, also, Dr. Fisher has been able to study the same types of Perrier that I had previously studied, in the Museum of Comparative Zoölogy, which adds to the value of the results.

Another good reason for repeating these discussions is the fact that the prestige of the great work of Sladen and the several important works of Perrier has caused the adoption of untenable nomenclature, even up to the present time, especially by several European writers.

In a very recent work (op. cit., 1912) Ludwig has very fully and satisfactorily discussed the genera *Pentagonaster* Gray and *Tosia* Gray, retained in the same sense as by me, in 1899, and by Fisher in 1911.

[1] This group has recently (1906) been renamed *Goniodiscides* by Fisher. Type *G. sebæ* (Müller and Troschel), *non* Gray. He properly rejected *Goniodiscus*, because it was essentially a synonym of Gray's genera. In my remarks on this group (1899, p. 149), the type was inadvertently stated as *cuspidatus*, instead of *sebæ*. But Dr. H. L. Clark has shown that *sebæ* is only a young *Culcita*.

He recognizes four species in each genus, thus reducing many nominal species to synonyms.

These genera are not found on either coast of America. The species are mostly Australian.

Subfamily *GONIASTERINÆ* Verrill.

Goniasterinæ VERRILL, Revision, p. 145, 1899. Fisher, op. cit., 1911*b*, p. 196, (includes *Mediasterinæ*).

Pentagonasterinæ (*pars*) SLADEN, Voy. Challenger, XXX, pp. 262, 264, 1889.

In this extensive group the dorsal and actinal plates are generally tesselated, polygonal, or rounded, often stellate, in pretty close contact, or else with intervening plates or ossicles of small size. They may be either granulated, or else smooth and naked, except for a marginal series of granules; sometimes they bear large conical tubercles or spines. Papulæ usually placed singly around the radial plates. Pedicellariæ, when present, foraminate and usually small, commonly with slender, flat, spoon-shaped or spatulate valves (plataleiform) and fossate; sometimes with large, wide, plain, short valves.

Genus **CERAMASTER** Verrill (as subgenus), Fisher.

Astrogonium (*pars*) MÜLLER and TROSCHEL, Syst. Ast., 1842.

Pentagonaster (*pars*) PERRIER, Révision, p. 20, 1876 (*non* Gray, 1840).

Pentagonaster (*pars*) SLADEN, Voy. Chall., XXX, p. 264, 1889 (*non* Gray). Perrier, Exp. Trav. et Talism., pp. 389, 390, 1894.

Tosia, subgenus *Ceramaster* VERRILL, Revision Genera, etc., in Trans. Conn. Acad., X, pp. 148, 158, 160, 1899.

Ceramaster FISHER, op. cit., 1911*b*, p. 204.

Philonaster KŒHLER, Investigator Exped., 1909, p. 74 (teste Fisher).

Form, short-rayed stellate. The marginal plates are very regular and generally correspond pretty closely in the upper and lower series, except distally; an odd interradial plate sometimes occurs abnormally; they are usually closely granulated, but sometimes have a small, naked central area, with rows of granules around the margins. Apical plate small. The abactinal plates of the radial areas are granulated, somewhat tabulate, their bases most often hexagonal or roundish, with lobes, and crowded pretty closely together, without special intervening or radiating connective ossicles, and usually without many secondary plates of small size; they sometimes extend to the apical plates. Superambulacral plates are lacking.

Interactinal plates are tesselated and granulated. The papular pores are usually rather numerous, generally placed singly in the angles between the plates of the basal radial areas, and sometimes

on the central part of the disk, but not on the triangular interradial areas, where the plates are angular and closely in contact.

The pedicellariæ are often lacking; when present they are small, elevated, usually with two, rarely three, spatulate or spoon-shaped blades, higher than broad, and set in special fossæ or pits of similar shape, in the surface of the plates. They may occur on any or all kinds of plates, either above or below, or on both sides.

The adambulacral spines are numerous, small and crowded. They grade more or less into the actinal granulation; the marginal furrow-series form a simple row of two to six or more; they are usually not much longer than those of the next series and not separated from them by a wide space. Distally, some of the spines of the second series usually become much larger and longer than the rest.

CERAMASTER GRANULARIS (Retzius) Verrill.

Plate IV, figures 1, 2; plate L, figures 2, 2*a* (details).

Asterias granularis RETZIUS, K. Vet. Akad. Nya Handl., IV, p. 238, 1783. Abildgaard, in Zoöl. Dan., fas. III, p. 19, pl. XCII, 1788. Retzius, Diss. Syst. Aster., p. 10, 1805.

Astrogonium granulare MÜLLER and TROSCHEL, Syst. Asteriden, p. 57, 1842. M. Sars, Oversigt af Norges Echinodermer, p. 46, 1861. Gray, Synopsis, p. 10, pl. 1, fig. 4, 1866. Verrill, Expl. by the Albatross in 1883, p. 542, pl. XVIII, figs. 48 and 48*a*, 1885. Whiteaves, Trans. Royal Soc. Canada, IV, p. 117, 1887.

Goniaster granularis LÜTKEN, Vidensk. Medd, nat. Foren., p. 146, 1865.

Pentagonaster granularis PERRIER, Révis. Stell. du Mus. Arch. de Zool. Expér. et Gén., V, p. 40 (224), 1876. Sladen, Voy. Challenger, XXX, p. 268, 1889. Bell, Catal. British Echinod. in British Museum, p. 73, pl. X, figs. 4, 5, 6, 1892. Verrill, Distrib. of Echinod., Amer. Journ. Sci., XLIX, p. 135, 1895. Danielssen and Koren, Asteroidea, Norske Nordhavs Exped., Zoöl., XI, p. 58, 1884.

Tosia (*Ceramaster*) *granularis* VERRILL, Revision Genera, etc., in Trans. Conn. Acad. Sci., X, p. 162, 1899. Whiteaves, Catal. Invert. E. Canada, p. 49, 1901.

The marginal plates, above and below, are closely covered with similar and small granules. The plates of the dorsal surface are hexagonal on the radial areas at the bases of the rays, and are mostly transversely elongated, and surrounded by six papular pores, corresponding to the angles. In the interradial areas they are transversely rhombic, often with the acute angles truncated, where pores intervene. All are closely covered with small angular granules.

The actinal interradial plates are crowded, polygonal, and closely covered with small, polygonal, granule-like spinules with rounded tips, about thirty on the larger plates, their size decreasing toward the marginal plates, where they are very small.

The inner adambulacral spinules form a simple marginal row, with three or four spines on each plate, of which the proximal is smaller and sets farther back, so as to be partly overlapped by the distal one of the preceding plate; the others are rather short, stout, blunt, scarcely tapered, about as long as the breadth of the adambulacral plates. Outside the furrow-series, each plate bears an actinal group of about seven to eleven short, stout polygonal spinules or granules, one of which occupies the center, while the others surround it; those on the side next the furrow-series are much larger and somewhat longer than the rest.

Oral spinules numerous, short, stout, polygonal, seven or eight on the border of the dentary plate, and a median or sutural epioral group, consisting of a row of six to eight on each plate, with two shorter intermediate or central rows of three or four smaller ones.

This is a truly arctic and circumpolar species. The description above is from a North Atlantic specimen, collected at Albatross Station, No. 2506, U. S. National Museum (Catalog No. 11428). I have seen no well preserved West Coast specimens perfect enough to figure.

Off mouth of Qualicum River, Straits of Georgia, in 40 fathoms (coll. G. M. Dawson, teste Whiteaves); Marmot Island, Alaska (Ives).

It has been taken off the northeastern American coast at several stations, between N. lat. 44° 28′ 30″ and 41° 47′, by the U. S. Fish Commission. Often taken by the Gloucester, Massachusetts, fishermen on the fishing banks, off Nova Scotia and Newfoundland, in 50 to 200 fathoms. Occurs off the northern coasts of Norway and Great Britain, and in the Arctic Ocean generally.

Bathymetrical range, 50 to 471 fathoms on the east American coast, rarely taken below 150 fathoms.

Mr. Ives recorded a specimen from Monterey, California, which is a very unlikely locality. Perhaps his specimen was *Mediaster æqualis*.

CERAMASTER PATAGONICUS (Sladen) Fisher.

Pentagonaster patagonicus SLADEN, op. cit., 1889, p. 269, p. 46, figs. 3, 4; pl. XLIX, figs. 3, 4. (Off Patagonia.)

Ceramaster patagonicus FISHER, op. cit., 1911*b*, p. 214, pl. XXXVII, fig. 4; pl. XXXVIII, figs. 1, 2; pl. LX, fig. 3.

Professor Fisher has described and figured a species that he thinks identical with the one described by Sladen from Patagonia, but without comparison of types.

The North Pacific form is a deep-water species and hardly comes within my limits, though Fisher has one locality in 41 fathoms, and one in 56 fathoms, off Unalaska, in Bering Sea. Other northern localities recorded by him are in 68 to 174 fathoms, from Bering Sea to Southeast Alaska, Behm Canal, 4 (?) to 134 fathoms. Also one specimen from Gulf of California, Carmen Island.

Possibly his northern specimens are like those placed by me under *C. granularis*. The two species are, apparently, very similar.

Dr. Fisher also describes the allied species, *C. japonicus* (Sladen), from deeper water, in Bering Sea and off Oregon, 184 to 786 fathoms; and *C. leptoceramus* F., from off Southern California, in 216 to 638 fathoms (op. cit., 1911*b*, p. 210, pls. XXXIX, LVIII, LX).

Genus **TOSIASTER** Verrill, nov.

Type, *T. arcticus* Verrill.

Pentagonal, with short rays. Marginal plates large, thick, coarsely granulated. Dorsal plates are stout, closely granulated; parapaxillæ with lobed or stellate bases, and tabulate tops. Papulæ widely distributed, not confined to the radial areas, usually in small groups of two to five.

Adambulacral plates are notably short; actinal side with four to six granuliform spinules; furrow-spines usually two or three to a plate.

Interactinal plates nearly rhombic, closely covered with angular granules.

Bivalve pedicellariæ occur on the marginal, interactinal, and adambulacral plates. Superomarginal plates often have a naked central area.

TOSIASTER ARCTICUS Verrill.

Plate L, figures 3, 3*a*; plate XCIX, figures 1, 2 (type).

Tosia arctica VERRILL, Amer. Journ. Sci., XXVIII, p. 63, July, 1909, figs. 8-8*a*.
Ceramaster arcticus FISHER, op. cit., 1911*b*, p. 219, pl. XL, figs. 1, 2; pl. LVIII, fig. 1; pl. LX, fig. 1.

The disk is pentagonal with short rays and thick, rounded margins. In alcohol the granules and most of the outlines of the dorsal plates are obscured by a soft, membranous or mucous structure. The marginal granules of adjacent plates are in contact and cover narrow channels between the plates, which have a low, round, columnar form when the granules are removed. Very small papulæ, standing in small groups, surround the plates.

Radii of the type, 31 mm. and 45 mm. to 50 mm. It grows to a much larger size.

The marginal plates are coarsely granulated. The upper ones often have a bivalve pedicellaria near the inner edge. The granules are unequal in size, angular, closely in contact, about eight in a transverse row on the larger plates. The marginal plates in the interradial region are squarish and pretty regular, and paired above and below; distally they become irregular, polygonal, with rounded corners, and often appear broken; they partially alternate in the two rows. The subapical plates are small; the apical or ocular plate is very small for this genus.

The lower marginal plates are closely granulated nearly all over, except a very small naked spot beneath. The upper ones also have a large naked spot, near the upper margin, covering about one-fifth of the surface of the plate, perhaps where the granules have been accidentally rubbed off. The actinal plates are large, mostly squarish; about three correspond to the breadth of each inferomarginal plate, proximally.

The dorsal plates are unequal in size, crowded, larger than in most related species, slightly and evenly convex, and very closely and coarsely granulated, the median radial and submedian rows mostly hexagonal, as well as most of the interradials. Along the interradial margins three to four dorsal plates correspond to one upper marginal. The granules are coarse, angular, unequal in size, flattish or a little convex, pretty closely in contact, mostly eight to ten on the larger plates.

Small valvular pedicellariæ, commonly a little larger than the granules, but often of about the same size, occur on a few of the dorsal plates, on the marginals, and also sparingly on the actinals. The valves, which in the larger ones project a little above the granules, are thin and flat, about as high as broad. They are mostly sunken in small, roundish, oblong or slightly bilobed pits.

The actinal interradial plates are granulated like the dorsals; they are more regular in form. Adambulacral plates often bear a bivalve pedicellaria; they have about six short, thick, angular spinules, crowded in two rows and all similar in height and size to the adjacent granules. The inner or furrow margin bears but two, or rarely three, short, thick spines.

This somewhat resembles *C. granularis*, but its granulation is much coarser, its margins thicker and more rounded, and its distal marginal plates more irregular. The adambulacral spines are much

coarser and fewer. Madreporite is large. Ambulacral feet have large terminal suckers.

It was known to me only from the Bering Sea and Siberia. The type (U. S. Nat. Mus.) was from Bering Island (N. Grebnitsky, 1899).

Fisher (1911*b*) records it from the Commander Islands, Shumagin Islands, Aleutian Islands; and Kadiak, Alaska, from low tide to 102 fathoms.

Genus **Amphiaster** Verrill.

Amphiaster VERRILL, Trans. Conn. Acad. Sci., 1, part 2, p. 372, February, 1878.

Stellate, with short, stout rays and large disk. Dorsal surface covered with large, stout, conical spines mostly one to a plate. Similar spines are borne by most of the marginal plates in both series. The marginal plates are unequal, few, large, convex or swollen, and naked in the middle, granulated around the edges. Dorsal abactinal plates are granular, polygonal, tesselated, surrounded by papulæ. Interactinal plates tesselated; each usually bears a spine. Adambulacral plates have a short row of marginal spines and a single larger spine on the actinal side. Only one species is known.

AMPHIASTER INSIGNIS Verrill.

Plate XCVIII, figure 2 (type).

Amphiaster insignis VERRILL, Trans. Conn. Acad. Sci., 1, part 2, p. 372, pl. IV, fig. 10, 1878.

A well grown specimen has the radii 50 mm. and 24 mm.; ratio, about 1 : 2. The marginal plates are alternately unequal; alternate ones bear a large, conical spine. There are about ten to twelve lower marginal plates and eight or nine upper ones, in adult specimens.

Three pretty regular, radial rows of spines on each ray, one to each of the principal dorsal plates; some may be lacking. Each of the interactinal plates usually bears a large central spine, elsewhere they are coarsely and evenly granulated.

Lower California; La Paz; Gulf of California. The types were from La Paz (Yale Museum).

Subfamily *MEDIASTERINÆ* Verrill, 1899.

Stellate, depressed, in form resembling *Ceramaster*. Dorsal radial plates paxilliform, or parapaxillæ, with circular or nearly circular bases, united together by radiating internal ossicles, about six to

each plate, producing a stellate structure, as seen from the inside. Supra-ambulacral plates are present. Pedicellariæ dorsal and ventral, sessile, bivalve, short and broad in the type; slender, two- or three-bladed ones may occur on adambulacral plates.

Papulæ mostly in radial rows, emerging from between the connective radiating ossicles, often two or three together.

The adambulacral spines are nearly as in *Ceramaster;* distal ones are larger and longer.

The principal reason for distinguishing this subfamily is the existence of radiating internal ossicles connecting the bases of the adjacent paxilliform plates.

This seems to be an important structural feature, and in the case of a family with so large a number of genera as Goniasteridæ, it is advantageous to subdivide it, if definite and important structures can be found for subfamily groups, as in this case.

Genus **Mediaster** Stimpson.

Mediaster Stimpson, Journ. Boston Soc. Nat. Hist., vi, p. 490, pl. 23, figs. 7-11, 1857. Verrill, Revision, in Trans. Conn. Acad. Sci., x, p. 178, 1899.
Mediaster Sladen, Voy. Challenger, Zoöl., xxx, pp. 263, 752, 1889. Fisher, op. cit., 1911*b*, p. 196.
Isaster Verrill, Proc. U. S. Nat. Mus., xvii, p. 257, 1894.

Form stellate, with a broad, flat disk and moderately long, tapered rays. Marginal plates well developed, not swollen, granulated, rather numerous, higher than broad, paired, upper and lower series nearly equal in size and number, and with their sutures more or less corresponding vertically, oblique in the type. No odd interradial plate. Abactinal plates or parapaxillæ are regularly longitudinally arranged, of moderate size, somewhat elevated, mostly roundish, covered with a rosette of short, obtuse spinules or elongated granules. When these are removed, the plates on the central part of the disk and along the median region of the arms appear as roundish or oval convex bosses. They are connected together by five or six internal radiating ossicles, between which are the pores for the papulæ. The papulæ may be single or (as in the type) clustered. Thus the plates appear to be stellate at the base, though they are not actually of that shape. The median row of abactinal plates extends to the apical plate of the rays in the type, but not in some of the other species. Some of the abactinal plates bear a central broad, sessile, valvular pedicellaria, which, in the type species, is nearly as wide as the plate. Pedicellariæ are sometimes lacking.

The adambulacral plates bear a regular marginal row of three to seven slender spinules, and usually two exterior longitudinal groups or rows of shorter spinules, which may be angular and obtuse; and toward the tips of the rays, some of them, in the type, become larger and longer, as in *Tosia* and *Ceramaster*. Some of these spinules may be replaced by spinuliform or clavate, two- or three-bladed pedicellariæ. The actinal disk plates are angular, often rhombic, closely arranged in rows parallel with the ambulacral grooves, covered with a rosette of granules, the central granules often replaced by a wide valvular pedicellaria. The dentary plates are not very prominent; each has an actinal row of larger spinules, similar to those of the oral margin.

This genus closely resembles *Ceramaster,* as limited above. The principal differences consist in the more elevated and convex abactinal plates, especially in the papular areas, where they are more widely separated by the large papular pores and united by intervening small internal ossicles, which give them a stellate appearance. On other parts of the disk, especially near the interradial margins, the plates are angular and closely joined in a mosaic, as in the former genus. The large valvular pedicellariæ are also, to some extent, characteristic, but the marginal, actinal, and dentary plates and their spinules are essentially the same in the two genera.

MEDIASTER ÆQUALIS Stimpson.

Plate II, figure 1; plate III, figure 1; plate V, figures 3-5 (details).

Mediaster æqualis STIMPSON, Journ. Boston Soc. Nat. Hist., VI, p. 490, pl. XXIII, figs. 7-11, 1857. Whiteaves, Trans. Royal Soc. Canada, IV, p. 117, 1887. Verrill, Trans. Conn. Acad. Science, I, p. 326, 1867; X, p. 179, pl. XXIV, figs. 10-12, 1899. Fisher, op. cit., 1911*b*, p. 198, pl. XXXV, figs. 1-3; pl. LIX, figs. 1, 1*a*-1*c*.

Rays five, variable in length, usually about equal to the diameter of the disk, regularly tapered, slender at the tip. Radii usually nearly as 1 : 3. Marginal plates, on each side of a ray twenty-two, above and below, in a specimen having the greater radius 36 mm. The plates on the margin of the disk are higher than wide, with the intervening sutures somewhat oblique. The lower marginal plates are similar in size and shape. All are closely covered with small, rounded granules. Abactinal areas of the rays are wide at the base, where they may consist of seven or nine rows of plates, but they rapidly decrease to three rows, and only the median row reaches the apical plate. The papular areas are large, covering nearly the whole

width of the proximal half of the rays, as well as most of the central disk. In these areas the plates are rounded or elliptical, convex, somewhat elevated, and separated by intervening spaces, in which there are usually five or six groups of papular pores, the individual pores being small and unequal, two or three or more forming each group.

Each of the larger abactinal radial plates is covered with a rosette consisting of about five to seven central and twelve to fourteen marginal, short, blunt, or clavate, granule-like spinules, rather longer than broad. Some of the disk-plates are larger, with more spinules. A large valvular pedicellaria often replaces the central group of spinules on some of the plates. These occupy nearly the whole breadth of the central area of the plate, and are narrowly oblong, not much elevated, with a nearly even and straight margin. Similar pedicellariæ, as well as some narrower ones, occupy the central area of some of the interactinal disk-plates.

The madreporic plate is small, sunken, with narrow, acute gyri. The central nephridial pore is small but distinct.

The actinal disk-plates are crowded and closely united; those next the adambulacral plates are squarish or rhombic and form regular rows, but those in the angles are smaller, irregular, and more rounded. All are covered with rosettes of granules, or short, obtuse, often prismatic spinules, rather larger and less regular than those of the upper side. A central valvular pedicellaria occurs on some of the plates, as stated above.

The adambulacral plates are squarish, not very large. Each bears a marginal row of three or four small, oblong, more or less prismatic or compressed, blunt spinules, the middle one usually a little larger than the others. External to these are two sets of shorter spinules, about three in each series; these sometimes form two rows, but in other cases are in a rosette-like group. Those next the inner or groove-series are longer than the others. One or more of these, especially distally, may be replaced by a spinuliform pedicellaria with two or three blades. On the distal part of the ray one or two of the spinules on the central part of these plates becomes considerably longer and larger than the rest. The oral spinules are similar to the adambulacral, but those at the tip of the oral plates are rather larger and more angular. The apical plates are rather small, prominent, somewhat obovate.

The preceding description is from a Californian specimen.

I have examined a natural-size photograph of the type of this species, furnished by Dr. R. Rathbun. It differs from the specimen

described above, only in having the rays somewhat longer. It is poorly preserved.

This species is closely allied to *M. bairdii*[1] Verrill, found in deep water off the east coast of the United States. The granulation of both surfaces is, however, decidedly finer in the latter, and there are various other differences as shown by the figures.

The colors in life are very bright. The dorsal side is usually deep red or vermillion; under side scarlet or orange, varying to salmon-color; ambulacral feet often red or scarlet.

Off Wilmington, California, 27 fathoms (U. S. Nat. Mus., specimen described above and figured); Queen Charlotte Islands, Malcolm Island, low water (Whiteaves); Departure Bay, British Columbia (C. H. Young, Canadian Geological Survey, 1909); off Victoria, Vancouver Island (C. F. Newcombe), very large.

Fisher records it from numerous localities, in 6 to 167 fathoms, from the Alaskan Peninsula to Lower California. Very common in 20 to 50 fathoms.

VARIATIONS.

Two specimens from Victoria, British Columbia, 1895, received from the Provincial Museum through C. F. Newcombe, are unusually large, and have an appearance quite unlike smaller specimens usually met with.

The larger has the radii 35 mm. and 115 mm.; dorsal parapaxillæ up to 4 mm. in diameter. The other has the radii 38 mm. and 103 mm. The rays are long and taper to slender tips. The under surface is coarse and rough in appearance, due to the large size and the length of the adambulacral spines and to the coarse spinules on the interradial plates.

The adambulacral spines are about the same in number and arrangement as on the smaller specimens, but are much increased in relative size; they are up to 3.5 mm. long. The same is true of the interradial spinules. These last stand in stellate groups, mostly of

[1] MEDIASTER BAIRDII Verrill. (Plate II, figure 2; plate III, figure 2.)

Archaster bairdii VERRILL, Amer. Journ. Sci., XXIII, p. 139, 1882.

Isaster bairdii VERRILL, Proc. U. S. Nat. Mus., XVII, p. 258, 1894. Amer. Journ. Sci., XLIX, p. 136, 1895.

Mediaster stellatus PERRIER, Mém. Soc. de France, IV, p. 268, 1891. Résultats des Campag. Scient., fas. XI, p. 46, 1896, pl. IV, figs. 1-1*d*.

Mediaster bairdii VERRILL, Trans. Conn. Acad., X, p. 181, pl. XXIV, figs. 1-9, pl. XXV, figs. 8, 8*a*, 1898.

Off the east coast of the United States, in 351 to 721 fathoms.

seven to nine, but often in a circle with one or two central on each plate. They are short, thick, mostly angular, often three-sided, mostly blunt, but many are acute and often beech-nut shaped. The central one is frequently replaced by a short, thick, bivalved, or sometimes trivalved, erect pedicellaria. In the larger specimen the spinules are erect in a close, round cluster, leaving open intervals between. In the other they are divergent, covering most of the interspaces. The inner adambulacral spines form a nearly straight, close row of three or four, which are nearly equal in length and more or less angular and blunt; the middle row usually consists of three or four similar but shorter spines in a curved or oblique series; outside of these, near the outer margin of the plate, are four to six much shorter angular spinules in a curved group, like those on the interradial plates. A bivalve pedicellaria sometimes replaces some of these. In a few cases all the spinules, except those of the inner row, form a circular, convergent group of about six nearly equal spines.

The dorsal parapaxillæ are very regular, circular, or broad-elliptical, evenly covered with large, rounded granules. About twenty to twenty-five granules form an outer circle on the larger plates; inside these is a second circle, usually of eight to twelve somewhat larger granules on the larger plates, or about six on the smaller ones; the center is occupied by a single round granule of similar size, or by two or three on the larger plates. Sometimes a small, stout, erect bivalve pedicellaria occupies the center. Sometimes it is one-third as broad as the plate.

The marginal plates are evenly covered with close, rounded granules; the marginal ones are a little larger and divergent over the margins, thus forming narrow covered channels between the plates. Some of the marginals bear small bivalve pedicellariæ, like those of the dorsal plates.

In one of these specimens the rays are considerably bent laterally, and some of them are twisted and have the tips upturned, showing more flexibility than the heavy plating would be expected to permit.

Subfamily *HIPPASTERIINÆ* Verrill.

Hippasteriinæ Verrill, Revision Genera, etc., in Trans. Conn. Acad., x, p. 174, 1899. Fisher, op. cit., 1911*b*, p. 223.

Antheneidæ (*pars*) Perrier and others.

This group includes stout, pentagonal or short-rayed starfishes, that have large, elongated, divergent, and differentiated adambulacral spines, one or two larger ones situated on the central part of

each plate. The dorsal and marginal plates are large, convex, bordered or covered with large granules, and often have one or more central tubercles or stout spines; no fascioles.

Bivalve pedicellariæ having short, broad valves, and often of large size, are usually present, both on the dorsal and actinal plates, and often on the marginals; smaller spatulate forms also occur.

The abactinal plates are thick, rather closely joined, and polygonal or roundish, usually unequal, with small intermediate secondary plates.

The actinal plates are numerous, tesselated, and covered with large granules, at least around the margin, and usually have either a large valvular pedicellaria or else a short, thick spine or tubercle in the middle. Superambulacral plates are lacking.

In this subfamily I include *Cladaster* Verrill, not included by Fisher. It lacks the large dorsal and marginal spines or conical tubercles of *Hippasteria,* and the dorsal ossicles are all of one kind. Fisher describes (1911*b*, p. 22, pl. XLI, figs. 1, 2) *C. validus,* Fisher, from off the Aleutian Islands, in 283 fathoms.

Genus **Hippasteria** Gray.

Plate XLVII; plate XLVIII, figures 1-5 (details of type species); plate XLIX, figure 6.

Goniaster (*pars*) AGASSIZ,[1] Prodromus, Mem. Soc. Sci. Neuchatel, I, p. 191, 1835 (*non* Gray, 1840). Forbes, Brit. Starfishes, p. 122, 1842. Norman, Ann. and Mag. Nat. Hist., XV, p. 123, 1865.

Hippasteria GRAY, Ann. and Mag. Nat. Hist., VI, p. 279, 1840; Synopsis, p. 9, 1866.

Hippasteria PERRIER, Arch. Zool. Expér., V, p. 86, 1876. Viguier, Arch. Zool. Expér., VII, p. 176, 1878 (structure). Sladen, Voy. Challenger, Zoöl., XXX, p. 341, 1889. Verrill, op. cit., 1899, p. 174. Fisher, op. cit., 1911*b*, p. 223.

Astrogonium (*pars*) MÜLLER and TROSCHEL, System Asteriden, p. 52, 1842.

Hippasterias BELL, Catal. Brit. Echinod., p. 76, 1892 (spelling incorrect).

Disk broad, rather flat, subpentagonal, with short rays, and concave interradial margins. Marginal plates of moderate size, thick, convex, regularly paired, surrounded by a marginal row of granules and usually bearing one or more short, stout spines or tubercles, and sometimes, also, a wide, bivalvular pedicellaria. Dorsal or abactinal plates mostly large, more or less convex, thick, tesselate, subpolygonal or roundish, with marginal granules, and bearing one or more thick central spines or tubercles, or else a wide bivalved pedicellaria; many small secondary, granulated plates are interspersed between

[1] See note, p. 286, for original contents of *Goniaster* Agassiz.

the larger ones, and may not have the central spine. Plates sometimes partially obscured by a thin integument.

Actinal plates rather large, angular, closely tesselated, arranged in rows parallel with the adambulacrals. They are surrounded by a row of coarse granules and bear either a large and wide bivalved pedicellaria, like those of the dorsal plates, or else one or more central tubercles. Sometimes nearly all of them bear large pedicellariæ.

Adambulacral plates large, but smaller than the interactinals, squarish, bearing a marginal row of large granules, or short, blunt spinules, one, or sometimes two, stout, central spines, and a longitudinal furrow-series of few, usually two or three, smaller divergent spines. (See pl. XLVIII, fig. 5.)

Oral or dentary plates large, bearing a marginal row of rather strong oral spines, besides two rows of shorter epioral ones on the actinal surface. (See pl. XLVIII, fig. 2.)

Median dorsal pore large, surrounded by papillæ. (See pl. XLVIII, fig. 4.) Tube-feet stout, with large suckers.

Madreporic plate rather small, with few coarse gyri. (Pl. XLIX, fig. 6.) Papulæ small, isolated, in the angles between the abactinal plates. (See pl. XLVIII, figs. 1-4.)

Besides the following species, Professor Fisher has described three deep-water species from the North Pacific. Neither of them has been recorded from within the limits of this report.

The North Atlantic and Arctic species, *H. phrygiana,* common on the coast of New England, in 50 to 200 fathoms, has not yet been found on the Pacific side. (See pl. XLVII; pl. XLVIII, figs. 1-5; pl. XLIX, fig. 6, for details.)

HIPPASTERIA SPINOSA Verrill.

Plate L, figures 4-4*c;* plate XCVIII, figure 1 (type).

Hippasteria spinosa VERRILL, Amer. Journ. Sci., XXVIII, p. 63, July, 1909. Fisher, op. cit., 1911*b*, p. 224, pl. XLII, figs. 1-3; pl. XLIII, figs. 1, 2; pl. LX, fig. 4.

Arms rather longer than in the Atlantic species. Upper surface thickly covered with rather slender, tapered, acute, unequal spines, nearly every plate bearing a single spine; those that do not have a spine carry a large central pedicellaria, about equal in diameter to the corresponding spine, but varying in size, like the spines, according to the size of the plate. The spines and pedicellariæ are surrounded at the base by one or more circles of granules borne on the plates

around the margins, leaving the mammilliform central part naked. The dorsal pedicellariæ are oblong-elliptical, as seen from above; the jaws are convex, usually a little wider distally than at the base, often nearly as high as wide. The upper marginal plates mostly bear two divergent spines, similar to those of the back. The lower marginal plates also bear similar, but shorter, spines, usually two, but sometimes one or three.

The actinal plates are coarsely granulated and each usually bears a large central pedicellaria similar to those of the dorsal surface in size and form, but usually rather higher and with the edges of the jaws distinctly denticulated.

Color, as dried, orange above, yellow below.

Greater radius, 80 mm., lesser radius, 40 mm.

The type specimen was taken at Departure Bay, British Columbia, in 18 fathoms, gravel, September, 1908 (Mr. C. H. Young, Canadian Geological Survey).

A smaller specimen from Puget Sound, sent by Professor Kincaid, has the radii 28 mm. and 65 mm. It agrees very well with the larger one in the number and form of the dorsal pedicellariæ and spines, but the latter are slightly less acute. The marginal plates of both series mostly bear two spines, like the dorsals, but rather larger, while there are often two or three additional, smaller, obtuse spines on the lower ones. The pedicellariæ of the actinal plates are numerous, about as high as long, and similar in size to the dorsals. The adambulacral spines are mostly not preserved. At the distal third there are two furrow-spines to a plate.

The specimens of this species described by me are from Puget Sound (Kincaid) and Departure Bay, British Columbia (Canadian Geological Survey).

Mr. Fisher (1911*b*) records it from many localities, from Kadiak, Alaska, to Southern California, in 27 to 121 fathoms.

Family *ODONTASTERIDÆ* Verrill.

Odontasteridæ Verrill, Trans. Conn. Acad. Sci., x, p. 201, 1899. Fisher, 1905, p. 302; 1911*b*, p. 153.

Gnathasterinæ (*pars*) Perrier, 1894, p. 251.

Form stellate with broad, short rays, or pentagonal. Marginal plates prominent, with an odd interradial plate in each row, normally.

The jaws bear one or two erect or recurved hyaline spines on the actinal (epioral) side, near the apex.

Abactinal plates are more or less paxilliform, parapaxillæ or protopaxillæ, with intervening large papular pores on the radial areas. The abactinal plates may bear clusters of more or less elongated spines, or a group of small granules. They usually form obliquely transverse lines on the rays, not always regular.

Interactinal plates angular, covered either with spines or with granules. Small, simple pedicellariæ sometimes occur on the actinal or abactinal plates. They may have two, three, or four papilliform blades.

Adambulacral plates usually bear elongated spinules, arranged in three or four small transverse rows; generally only two or three in the furrow-series; sometimes only one. Dentary plates usually have elongated, acute marginal and apical spines. They are sometimes closely united along the median suture; in other cases (*Odontaster*) they are separated by a space covered only by membrane.

The marginal plates are covered either with spinules or with granules, sometimes the upper ones are granulated and the lower spinulose, like the corresponding disk-plates; they usually have deep-fasciolated sutures.

Ambulacral feet have suckers. No superambulacral plates.

Genus **Odontaster** Verrill.

Odontaster Verrill, Amer. Journ. Sci., xx, p. 402, 1880; Proc. U. S. Nat. Mus., xvii, p. 262, 1894; Amer. Journ. Sci., xlix, p. 136, 1897; op. cit., 1899, p. 205.

Gnathaster Perrier (*pars*), Exp. Trav. et Talism., p. 244, 1894.

Odontaster Bell (*pars*), Proc. Zoöl. Soc. London, p. 260, 1893. Fisher, op. cit., 1811*b*, p. 154.

A single, odd, hyaline, recurved, movable spine on the apex of each jaw. Dentary plates large, separated by an open, fusiform space, covered by membrane. Abactinal surface covered with elevated, convex, or clavate paxilliform plates, or parapaxillæ, which usually bear clusters of elongated spinules, like true paxillæ; their bases are stellate. Upper marginal plates are usually finely spinulated. Lower marginal plates are generally large and placed singly or in the angles around the radial paxillæ. The radial abactinal plates form more or less evident obliquely transverse rows and extend nearly or quite to the apical plate.

The odd interradial marginal plate is usually triangular or wedge-shaped. Simple pedicellariæ occur rarely.

The adambulacral plates usually bear several rows of spines; usually three or four in the furrow-series, rarely but two.

The open suture between the dentary plates of the jaws; the movable hyaline spine, attached only by its base, at the apex of the jaw, together with the very spinose character of the abactinal paxillæ and marginal plates, separate this genus from its allies. The marginal plates are also larger than in most of the other groups, and the adambulacral plates bear usually three or four spines in the furrow-series.

ODONTASTER CRASSUS Fisher.

Odontaster crassus FISHER, op. cit., 1905, p. 302; op. cit., 1911*b*, p. 154, pl. XXIX, figs. 1-4; pl. LVI, fig. 6.

Form stellate with short rays; radii of the type, 13 mm. and 21 mm.; ratios, about 1 : 1.5. Marginal plates few, massive, eight in a row in the type, covered with granule-like spinules. Odd epioral hyaline spine is lanceolate, recurved. Interactinal plates squarish, bearing five to twelve radiating, short, stout, pointed spinules.

Dr. Fisher records it from ten stations, in 43 to 284 fathoms, from off Monterey to San Diego, California.

Family *ASTEROPIDÆ* Fisher.

Gymnasteriidæ PERRIER, 1884, pp. 165, 229. Sladen, 1889, p. 355.
Gymnasteriidæ + *Poraniidæ* PERRIER, op. cit., 1894, pp. 163, 227.[1]
Asteropidæ FISHER, 1908, p. 90; 1911*b*, p. 247.

Disk usually large; rays short and broad. Dorsal ossicles sometimes tesselated, in regular radial rows, more often irregular, sometimes partly abortive, sometimes reticulated; either covered with a thick, smooth or granulated skin, or spinose, or spinulose.

Marginal plates various, sometimes prominent, usually oblique or overlapping, sometimes with a small group of spinules on the outer edge, or with a single spine; sometimes nearly abortive, and the edge of disk thin.

Interactinal plates sometimes numerous, usually in regular oblique rows. Papulæ in dorsal radial areas, sometimes intermarginal. Pedicellariæ commonly lacking; when present, valvular, with two to four valves.

[1] It seems to the writer very doubtful whether the Poraniidæ should be combined with this family. Some of the genera are very similar to Asterinidæ in form and structure.

Subfamily *ASTEROPINÆ* Verrill, nov.

Margins not thin; upper and lower marginal plates well developed, subequal. Dorsal skeleton well developed, the plates tesselated or stellate-reticulate, with or without spinules or spines. Superomarginal plates sometimes with stout spines. Interradial plates numerous, in chevrons. Adambulacral spines few. Pedicellariæ, when present, bivalve or multivalve.

The Poraniinæ differ in having the marginal plates feebly developed, more unequal, the edges of the disk being thin in most cases, and formed by the inferomarginals; the dorsal plates are irregular, often partly or nearly all abortive, not forming a regular median row, and usually concealed by a thick, smooth, or else finely spinulose dermis; interactinal plates fewer, in oblique rows, or nearly abortive, or in detached, transverse rows (*Tylaster*), with or without spinules. Pedicellariæ generally lacking.

Genus Dermasterias Perrier.

Dermasterias Perrier, Révision Stell., Arch. de Zool. Expér., v, p. 98, 1876. Viguier, op. cit., vii, p. 218, 1878. Sladen, Voy. Chall., Zoöl., xxx, pp. 355, 375, 1889. Fisher, op. cit., 1911*b*, 248.

Asteropsis (*pars*) Grube, Wieg. Arch., xxiii, 1857. A. Agassiz, North Amer. Starfishes, Mem. Mus. Comp. Zoöl., v, p. 106, pl. xv (structure).

Some of the characters of this genus have not been correctly stated by several previous writers.

It has more or less numerous small pedicellariæ scattered irregularly over the dorsal surface.[1] These are partly bivalve and partly trivalve, while four-valved ones often occur. The valves are small, thick, obtuse or rounded. Five-valved ones are rarely seen; three-valved ones are often the most numerous. Other pedicellariæ, of much larger size, often occur just outside of the bases of the inner adambulacral spines. They may stand in a single row, or they may be crowded into two or three rows. (Pl. vi, figs. 4, 5.) They are mostly bivalvular, with wide, short, truncate jaws, but some of them have three jaws (pl. vi, fig. 5, *P' P'*); occasionally one occurs with four smaller jaws.

On one of the young specimens, they nearly cover the surface, and most of them have four valves; some have three, and a few five valves. (See pl. l, figs. 1-1*b*.)

[1] Perrier (Révis. Stell., p. 98, 1876) gives the absence of pedicellariæ as a character of the genus. On some specimens from Puget Sound they are very numerous on the dorsal side (var. *valvulifera* Verrill).

The adambulacral spines, which are usually two to a plate, inner and outer, increase in length and become terete, instead of flat, at the tips of the arms, while some of the distal interactinal and inferior marginal plates sometimes bear short, thick, stumpy spines, especially in large specimens.

In formalin preparations the entire surface is covered with a thick, soft skin, deep brown or yellowish brown in color, which entirely conceals the ossicles and spines (pl. XXIX, fig. 2), but the groups of papulæ on the back are quite distinct. In life this skin is very soft and covered with abundant mucus. In some dried preparations the integument is like a sort of thin varnish over the surface, leaving the ossicles easily visible, but in other cases it is so dried that the ossicles are mostly concealed. The principal dorsal ossicles, both on the rays and on the disk, have a regular stellate arrangement, as stated by Agassiz. Each large ossicle is roundish, with slight lobes, connected with five to eight small, radiating connective ossicles. In the interradial regions the ossicles are stouter, are not stellate, and are closely imbricated. In this area there are few or no papulæ. The interactinal plates are broad ovate, and form rows parallel to the ambulacra. They are distinctly alternatingly imbricated, like slates on a roof. Papulæ are very numerous and form large groups on the dorsal side of large specimens, but stand singly on young ones.

There is an incomplete, partly calcified interradial septum, extending outward from the jaws, composed of rather large rounded ossicles. Superambulacral plates (?) of small size are present. For some details of the skeleton see pl. LXXXVI, figs. 2-2*d*.

Only one species of the genus is known.

DERMASTERIAS IMBRICATA (Grube) Perrier.

Plate VI, figures 3, 4, 5; plate XXIX, figure 2; plate L, figures 1-1*b* (pedicellariæ); plate LXXXVI, figures 2-2*d* (skeleton); plate XCVII, figures 2-2*b* (variety).

Asteropsis imbricata GRUBE, Wieg. Archiv, XXIII, p. 340, 1857. Verrill, Trans. Conn. Acad. Sci., I, p. 324, 1867 (distribution). A. Agassiz, North American Starfishes, p. 106, pl. XV, figs. 1-7, 1877 (structure).

Dermasterias inermis PERRIER, Révision Stellérides, p. 282, 1875.

Dermasterias imbricata PERRIER, Arch. de Zool. Expér., V, p. 98, 1876. Viguier, op. cit., VII, p. 218, 1878. Sladen Voy. Chall., XXX, p. 766, 1889. Whiteaves, Trans. Royal Soc. Canada, IV, p. 117, 1887. Clark, Proc. Boston Soc. Nat. Hist., XXIX, p. 325, pl. I, figs. 1, 2, 1901. Fisher, op. cit., 1911*b*, p. 249, pl. XL, figs. 1, 2; pl. LVI, fig. 1.

The disk is large, rather plump in life, with five short, tapering rays (rarely six), but the length of the rays is subject to considerable variation. The radii of a short-rayed Alaskan specimen measure 50 mm. and 120 mm. A long-rayed one, from the same place, measures 35 mm. and 110 mm.

Surface smooth and lubricous in life, owing to the thick, soft skin. When dried, the ossicles are more or less distinctly visible on both sides. Those of the back have a rather regular stellate arrangement on the disk and bases of the rays.

Many specimens have numerous small, scattered, dermal dorsal pedicellariæ, mostly bivalve or trivalve, but often quadrivalve, as described above, under the genus. In many specimens they are lacking.

Larger ventral pedicellariæ are often present. In most cases they form a single row, more or less concealed under the free edge of the dermal membrane in dried specimens. In nearly all cases they take the place of the outer row of adambulacral spines, for they occupy the same position on the plate. Spines are absent when pedicellariæ are present; sometimes the latter will form regular rows for half the length of the grooves, and then spines will take their place on the distal half, or they may alternate irregularly with spines. The breadth of these pedicellariæ is almost the same as that of the spines, but they are not half as long. Many specimens lack these ventral pedicellariæ entirely.

In one lot of twenty-three dried specimens from Sitka, four had few or no dorsal pedicellariæ; nineteen had dorsal pedicellariæ; five of these had large numbers; twelve had them both on the dorsal and on the ventral side; five had numerous actinal ones.

Their presence does not depend upon age, for they are lacking on some of the largest specimens, while they are numerous on others. They are abundant on some of the young ones, about 60 mm. in diameter.

The color, in life, according to Prof. W. R. Coe, is deep orange to dull red.

One small, six-rayed example was found by Professor Coe (pl. VI, fig. 3); its radii are 7 mm. and 14 mm.

This species is common from Monterey Bay, California, to middle Alaska. Numerous specimens were collected at Sitka, etc., by Prof. W. R. Coe, on the Harriman Expedition. It lives at and just below low tide. It is also common in Puget Sound, whence I have seen many specimens. Several large specimens have been sent to me by

the Canadian Geological Survey, from British Columbia and the Queen Charlotte Islands, Vancouver Island, etc. It has not been recorded except from very shallow water or between tides. Dr. Fisher's records are from Sitka to Monterey, California, shores,

DERMASTERIAS IMBRICATA, var. VALVULIFERA Verrill, nov.

Plate XCVII, figures *2-2b*.

This name is proposed for the form of this species having many (often very numerous) valvular pedicellariæ on the dorsal surface. Usually there is also a row on the actinal side, external to and parallel with the inner adambulacral spines, while others may occur on the interactinal areas, either centrally or more often proximally, near the jaws, in pairs. The actinal pedicellariæ mostly have two broadly rounded jaws, sometimes three; those of the dorsal surface mostly have three or four narrower valves, but some may have two; others five or six jaws (see pl. XCV, figs. *2-2b*). The specimen figured from Sitka has the radii 24 mm. and 38 mm.; another from the same place has the radii 38 mm. and 77 mm. Larger specimens occur.

Except for the presence of many pedicellariæ this variety does not differ much from the ordinary variety with few or no pedicellariæ. This does not depend upon age, for both large and small specimens occur of each form. Very young specimens, as usual in other genera, lack pedicellariæ.

All the specimens seen are from southern Alaska, at Sitka, etc.

Family *OPHIDIASTERIDÆ* Verrill.

Ophidiasteridæ VERRILL, Trans. Conn. Acad. Sci., 1, part 2, p. 344, 1867.
Linckidæ PERRIER, Révision Stellérides, p. 117, 1875.
Linckiidæ SLADEN (*pars*), op. cit., 1889, p. 397. Fisher, op. cit., 1911*b*, p. 240.
Linckiadæ VIGUIER, Squelette des Stell., p. 144, 1879.

Form stellate, usually with five slender rays, but the number is variable in some autotomous species. Marginal plates usually small and not conspicuous. Abactinal and marginal ossicles usually tesselated or subimbricated, in most cases granulose (covered with rather thick, smooth skin in *Leiaster*), rarely spinose.

Papulæ usually numerous, mostly abactinal and lateral in groups, sometimes single; in the majority of the genera they occur also below the marginals, or between the interactinal plates.

Adambulacral plates with either granules or spinules.

Pedicellariæ often lacking; when present, usually bivalve, sometimes spatulate and excavate or fossate. Superambulacral plates often present.

Genus Linckia Nardo.

Linckia NARDO, Oken's Isis, 1834, p. 717. Gray, op. cit., 1840, p. 284; System, p. 13, 1866. Verrill, op. cit., 1867, p. 285. Sladen, op. cit., 1859. Fisher, op. cit., 1911*b*, p. 242.
Ophidiaster (*pars*) MÜLLER and TROSCHEL, Syst., p. 28, 1842.
Phataria MONKS, op. cit., 1903, p. 35 (*non* Gray).

Disk small, rays long, slender, nearly terete, usually variable in number. Some species are autotomous. Adambulacral plates bear granule-like structures, in two series. Papulæ lacking on actinal side, numerous in abactinal areas. Abactinal plates irregularly arranged. Pedicellariæ not observed.

LINCKIA COLUMBIÆ Gray.

Linckia columbiæ GRAY, op. cit., 1840, p. 285; Synopsis, 1866, p. 14. Sladen, op. cit., 1889, p. 784. Verrill, op. cit., 1867, pp. 332-334. Fisher, op. cit., 1911*b*, p. 242, pl. XLVIII, figs. 1-7.
Linckia diplax PERRIER, Révision Stell., p. 144, 1875.
Phataria (*Linckia*) *fascialis* MONKS, op. cit., 1903, LV, p. 351 (autotomy and variations).
Phataria (*Linckia*) *unifascialis*, var. *bifascialis* MONKS (*non* Gray); op. cit., 1904, LVI, p. 596, pl. XLII (autotomy, variations, etc.).

This species is probably not to be found within the proper bounds of this report. It is introduced chiefly because of the great interest connected with the remarkable variability, autotomy, powers of restitution of lost rays, or even of the entire body, from a part of one ray, etc., which have been so well and carefully studied and described by Miss Sarah Monks, in the works cited above.

Other species of the genus share these peculiarities, for example *L. guildingii*, which I have studied in Bermuda.

Miss Monks, op. cit., 1904 (pp. 596-600), has shown that this species is very variable in number of rays, madreporites, etc. The variations in number of rays are mostly due to autotomy and irregular restoration of rays, so that there may be from five to eleven rays. Though five is the normal number, regularly six-rayed specimens are common.

She found many in the " comet-form " and succeeded in producing such forms by cutting off rays at some distance from the disk. These, in the course of six months, produced a " comet-form " with a new disk.

Two madreporites are common, and as many as five may occur.

Two dorsal pores were more frequent than one, in the proportion of 48 to 15; eleven had three, two had four, and one had five. The genital products issued from various points along the rays.

Its range is from Southern California, San Pedro, San Diego, etc., to Panama and West Colombia and the Galapagos Islands. Very common at La Paz, Lower California. It occurs from low tide to 30 fathoms.

Fisher erroneously quotes "*L. ornithopus*" Verrill, 1867, as a synonym of this species. No such determination by me occurs in the work cited or elsewhere. On page 344, *L. ornithopus* is given as an Atlantic species, "probably identical" with *L. guildingii*.

Suborder **MYONOTA** Ludwig.

Each ray has a pair of strong internal dorsal muscles, extending for part or most of its length. Papular areas localized. Pedicellariæ usually pectinate. Podia with suckers.

Family *BENTHOPECTINIDÆ* (Verrill) Fisher.

Benthopectinidæ and *Pontasterinæ* Verrill, Trans. Conn. Acad. Sci., x, pp. 200, 217, 1899.
Pararchasteridæ Sladen, op. cit., 1889, p. 4.
Notomyota (order) Ludwig, 1910, p. 435.
Benthopectinidæ Fisher, 1911*b*, p. 120.

An almost strictly deep-sea family. Form stellate; disk rather small; rays five, elongated, with two rows of thick, spinose, marginal plates, which are not exactly paired, but are sometimes alternate, or nearly so, and have no definite fasciolated grooves between them; there is an odd interradial marginal plate in each row, in some genera (Benthopectininæ). Pedicellariæ are pectinate or fasciculate, rarely bivalvular.

Dorsal abactinal surface is covered by protopaxillæ, spinose parapaxillæ, or simple spinose plates, rarely with true paxillæ.

Papulæ may be distributed over most of the lateral surface of the rays, or may be limited to the proximal part of the rays, or concentrated in specialized areas (*papularia*) near base of rays.

Actinal interradial area is small or nearly abortive; it is sometimes occupied by one or more large pectinate pedicellariæ.

Similar pectinate pedicellariæ may occur between the plates, on the margins, or on the dorsal surface. Adambulacral plates are angular and have elongated furrow-spines and one or more enlarged actinal spines. No superambulacral plates.

A pair of muscle-bands extends along the medio-dorsal region for a part of the length of the rays. Dorsal pore usually distinct. Ambulacral feet have suckers.

Ludwig (1910) has proposed a special order (Myonota) for this family, on account of the presence of dorsal radial muscle-bands.

It seems to me desirable to retain two subfamilies in this group, though recently discovered genera render them less distinct than formerly.

Subfamily *BENTHOPECTININÆ* Verrill, 1894, p. 245.

Benthopectinidæ (family) VERRILL, 1899, p. 217. Ludwig, 1910, p. 435.

This group will include those genera in which an odd interradial marginal plate normally exists in part or all the interradial areas in both rows. The papulæ are not concentrated in specialized papularia, though they may be confined, in some genera, to the basal part of the rays. Abactinal plates are flat or low tabulate, usually lobed, sometimes stellate, bearing one or more large, sharp spines and usually many smaller accessory spines.

This is a strictly deep-sea group. Several species have been described by Dr. Fisher from the North Pacific. It includes the genera *Benthopecten* Verrill; *Myonotus* Fisher; and *Nearchaster* Fisher.

Subfamily *PONTASTERINÆ* Verrill, 1899.

Cheirasteridæ (family) LUDWIG, 1910, p. 435.
Benthopectinidæ (*pars*) FISHER, op. cit., 1910, p. 120.

Odd marginal interradial plates are not normally present. Papulæ are confined to the basal parts of the rays, and are often concentrated in specialized papularia.

This group is almost entirely confined to the deep sea. Several species are known from the North Pacific in deep water. Only one comes within my bounds.

Genus Luidiaster Studer.

Acantharchaster VERRILL, Proc. U. S. Nat. Mus., XVII, p. 268, 1894.
Luidiaster STUDER, 1883, p. 131. Ludwig, 1910, p. 451. Fisher, op. cit., 1911*b*, p. 127.

Rays usually five, angular, tapered. Disk small. Interradial actinal plates few, confined to the disk, spinous. Marginal plates of moderate size, more or less alternate, spiniferous; those of the upper series smaller than those of the lower, rounded, with a central

eminence bearing a single large, movable spine, with a group of small spinules around its base. The plates of the lower series may bear two or more similar large spines surrounded by spinules. The upper marginal plates form a narrow margin along the rays.

The dorsal surface is covered with small, unequal plates in the form of protopaxillæ and spinose parapaxillæ.[1] The latter have a low, round column and bear a large, central, articulated spine surrounded at base by a circle of small spinules; they are found on the disk and along the median part of the rays. The protopaxillæ are smaller, and part of them bear only small spinules; others have a small central spine. The papulæ occur on most of the disk and the entire basal part of the rays.

Peculiar double pectinate and fascicled pedicellariæ exist on the dorsal surface of the rays and disk, and a single one, of larger size, occupies the center of each actinal interradial area (see pl. XXXIV, *P, P*); in one case a similar structure replaces the two upper marginal plates in the interradial angle. These large actinal compound pedicellariæ may have ten to twelve incurved papillæ on each side, while those of the dorsal surface have usually three to six. Some of the latter have three convergent groups of curved papillæ. The central, dorsal nephridial pore is very evident and is surrounded by papillæ. The adambulacral plates have a salient inner angle, and bear a horizontal divergent group of furrow-spines and a transverse actinal row of long spines. The jaw-plates are large and bear simple marginal and actinal series of long spines.

LUIDIASTER DAWSONI (Verrill) Ludwig.

Plate XXXIII; plate XXXIV; plate XXXV, figure 2 (type).

Archaster dawsoni VERRILL, in Whiteaves, Report of Progress of Geological Survey of Canada, for 1878-79, p. 194*b* [p. 5], 1880.

Acantharchaster dawsoni VERRILL, Proc. U. S. Nat. Mus., XVII, p. 269, 1894. Fisher, 1910, p. 549.

Luidiaster dawsoni LUDWIG, 1910, p. 452. Fisher, 1911*b*, p. 128, pl. XXV, fig. 2; pl. XXVI, fig. 3; pl. XXVII, fig. 2; pl. LV, figs. 3, 3*a*; pl. LVI, fig. 5; pl. CXIX, fig. 2; pl. CXX.

Rays five, long, acute. Radius of the disk, 17 mm.; of rays, 100 mm.; ratio, 1:6, nearly. The rays are long, flat, regularly tapered. The upper surface is loosely covered with small ossicles (protopaxillæ), those toward the margins of the rays bearing only circular groups of very minute short spinules; but along the middle

[1] See pages 280, 281, for explanations of these terms.

region of the rays and over the disk they are spino-parapaxillæ, each bearing a long, tapering, acute central spine, surrounded at base by a circle of small spinules. Between the plates there are, over nearly the whole surface, numerous papular pores. Along each ray, toward the marginal plates, there are, at irregular intervals, singular pectinate pedicellariæ, consisting of groups of small incurved spinules. Usually there are two, three, or four clusters. Each cluster, consisting of a row of three or four to six curved spinules, form one group; and the ends of all the spinules converge to a pore in the center of the group. A much larger elliptical one, composed of ten to twelve spinules on each side, occupies each actinal interradial area.

The upper marginal plates are small, but prominent, and each bears a long, rather stout, acute, erect spine, surrounded at base by a group of slender, unequal spinules. The lower marginal plates mostly bear three long and large divergent spines, the upper one largest, and rather longer than those of the upper plates; between and around their bases there are slender spinules. The adambulacral plates bear upon the inner edge a rounded group of about six very slender, blunt spines; the two lateral ones are very short; the middle ones, long; outside of these there is a transverse row, usually of three much longer and larger blunt spines.

Dixon Entrance, British Columbia, 11 fathoms (type, collected by Dr. G. M. Dawson, 1885).

Dr. Fisher records it from eleven stations, in 56 to 159 fathoms, from Bering Sea to Kadiak, Alaska.

Suborder **PAXILLOSA** (Perrier), emended.

Paxillosa Perrier (as an order), Expéd. Trav. et Talism., pp. 28, 29.
Paxillosa Verrill, Trans. Conn. Acad., x, pp. 199, 200, 201, 1899.

These are Phanerozona in which the two rows of marginal plates are usually well developed and often spinose, and usually have well developed fasciolate grooves between them. The dorsal or abactinal plates are usually developed in the form of true columnar paxillæ or spinopaxillæ, sometimes as pseudopaxillæ. Pedicellariæ are often present, usually consisting of several connivent papillæ, or spinule-like structures, surrounding a pore. Sometimes forceps-like forms occur.

Bivalve valvular pedicellariæ are lacking. Ambulacral feet are generally pointed; sometimes flattened and natatory; rarely with a small terminal knob, but without a sucker.

Ambulacral ampullæ single or double. Dorsal pore present or absent. Superambulacral plates usually present; sometimes absent.

The Paxillosa should only include such groups as have neither true bivalve pedicellariæ nor sucker-feet. The existence of true paxilliform plates on the dorsal surface cannot be made an invariable diagnostic character, for they occur in some forms of *Valvulosa*. The development of the ambulacral feet varies much in both groups, and depends mainly on the nature of the bottom commonly inhabited.

The families represented in shallow water on the Northwest coast are Porcellanasteridæ, Astropectinidæ, and Luidiidæ. See families enumerated on page 283. The only family not represented is Goniopectinidæ, a deep-sea group.

Family *ASTROPECTINIDÆ* Gray (restricted).

Astropectinidæ (*pars*) Gray, Ann. and Mag. Nat. Hist., p. 140, 1840; Synopsis, p. 2, 1866. Sladen (*pars*) Voy. Challenger, xxx, p. 174, 1889 (includes *Luidia*).

Astropectinidæ Sladen, op. cit., 1859, p. 175.

Astropectinidæ (sense extended) Fisher, op. cit., 1911*b*, p. 37. (Analytical table of all recognized genera).

Paxillosa in which the disk is usually small or of moderate size, the rays often much elongated. The dorsal surface is generally covered with highly developed true paxillæ (rarely with parapaxillæ or pseudopaxillæ), commonly covering fasciolated interspaces with intervening simple papulæ.

Both rows of marginal plates are usually large, the inferomarginals often the larger. They are either granulated or spinulose and often very spinose, with more or less simple fasciolated grooves between them; not covered by a thick skin. Adambulacral plates usually spinose on the actinal surface and with a divergent row of furrow-spines, without a web.

Pedicellariæ are often lacking; when present usually fasciolate or spiniform, or consisting of two short connivent rows of spinules surrounding a special pore. Ambulacral feet in two rows, large, usually pointed, never with suckers. Ampullæ double. Dorsal glands and pore usually present. Superomarginal plates present. Interactinal plates wanting, or more or less numerous in regular simple rows, usually spinulose and with fasciolated grooves between all the rows, but without marginal webs.

The aproctous condition, formerly supposed to be characteristic of the family, is unreliable, for in nearly all the genera referred to it

by Mr. Sladen there is a perfectly well defined dorsal or " anal " pore, and in some of the genera the pore is even elevated on the summit of a dorsal cone or chimney (*Psilaster, Ilyaster,* etc.). This pore, which I have designated as *" pseudanus "* or *" nephridial pore,"* serves in each of these families (and in Asterioidea generally) mainly for the discharge of the secretion of the branched, dorsal, glandular organs, probably nephridial in function, situated above the stomach and often called *" cæcal appendages."* These glands are sometimes absent. Whether the central pore serves as a true anus in any of these starfishes is very doubtful, for the intestine is usually nearly or quite abortive. In any case, it is often impossible to ascertain this point without actual dissection of alcoholic or fresh specimens, which are often not available.

I have been unable to demonstrate a functional intestine in any case, and have never observed fœcal matter in the so-called intestine; nor have I ever seen such substances discharged by the dorsal pore by any living starfish, though I have studied thousands of living specimens, including numerous genera and families. In Pterasteridæ, however, the intestine is very obvious.

The existence of definite fascioles of specialized spinules or papillæ on the margins of the plates, so as to form covered channels along their sutures, in this and the related families, is evidently a character both of morphological and of physiological importance. The existence of such fascioles is correlated with the mode of life. Such forms as have them appear commonly to live more or less buried in soft mud or sand, and the fascioles are evidently for the purpose of providing a free circulation of water around the whole surface of the body, both to provide for respiration and to keep the surface of the body free from dirt. The paxilliform plates and spinules also contribute to both these functions and also serve to protect the dermis and papulæ from dirt.

The typical Astropectinidæ are among those best provided with fascioles and with the most highly developed forms of paxillæ. They are also those that are eminently dwellers on and beneath mud and sand. The pointed form of the ambulacral feet is correlated with the same habit, but they are not confined to such places.

The genera *Ctenodiscus, Porcellanaster, Luidia,* and allies have similar but even more specialized, structural adaptations for the same purposes.

Dr. Fisher thinks that it is not possible to divide the family into subfamilies, as others have done. Owing to the recent discovery, in

the deep sea, of numerous more or less intermediate genera, the limits of such groups, as well as those of recognized families and genera, have become more and more indefinite. Probably future discoveries will make them even more so.

Still it is convenient to recognize subfamily groups, even if not always closely definable by any one or two characters. It is the combination of several characters that counts most in all the larger groups.

ANALYTICAL TABLE OF NORTHWEST AMERICAN SHALLOW-WATER GENERA OF ASTROPECTINIDÆ.

Marginal plates thick, convex, spinulose on the whole surface; separated by deep sutural grooves, which are usually bordered by many rows of fine fasciolated spinules. Interactinal plates, when present, convex, spinulose, pseudopaxilliform, and fasciolated.

A. Marginal plates of both series large; lower ones mostly much prolonged, reaching the adambulacrals. Dorsal plates are true columnar paxillæ; interactinal plates few or none. Rays elongated.
Astropecten (restricted).

AA. Lower marginal plates are not so much prolonged adorally. Interactinal plates are in rows, forming a triangular area.

B. Dorsal plates form convex pseudopaxillæ with stellate bases; interactinal plates are flat or convex pseudopaxillæ, in three or more paired rows, with an odd interradial row; not evidently imbricated; lower marginal plates are about equal in length to two adambulacrals; spinose centrally. Rays rather long. Marginal fasciolated grooves are simple and narrow. Adoral marginal adambulacral spines are deep in the grooves.
Bunodaster. Type, *B. ritteri* Verrill.

BB. Dorsal plates are true columnar paxillæ or parapaxillæ.

C. Lower marginal plates are usually spinose and spinulose, as in *Astropecten.* Rays elongated.
Astropectinides Verrill. Type, *A. mesacutus* (Sladen). Antarctic.

CC. Marginal plates not spinose, but covered with minute spinules; sutural grooves wide and deep. Rays short or rather short. Odd actinal interradial plates are present.

D. Marginal plates short and about equal in number to the adambulacral plates; upper ones much smaller than the lower; both series become oblique distally, the sutures slanting adorally. Actinal plates have a raised center, or carina, and strong lateral fascioles.
Leptychaster Smith. Type, *L. kerguelenensis.*

DD. Marginal plates few, large, subrectangular, subequal in breadth, each about as long as two adambulacrals; grooves wide, not notably oblique distally. Interactinal plates fasciolated, in three or more rows, rounded, convex, tabulate, not carinate; a few unpaired ones.
Glyphaster. Type, *G. anomalus* (Fisher).

Genus **Astropecten** Gray (emended).

Astropecten (*pars*) Gray, Ann. and Mag. Nat. Hist., vii, p. 180, 1840; System, p. 3, 1866. Müller and Troschel, Syst. Aster., p. 67, 1842. Sladen, op. cit., 1889, p. 193. Fisher, op. cit., 1911*b*, p. 55.
Stellaria Nardo, Oken's Isis, p. 716, 1834 (*non* Müller, Mollusca, 1832).
Asterias L. Agassiz, Prod., p. 191, 1835.

Rays more or less elongated, subacute, flat above, with true abactinal, stellate paxillæ, and stout, fasciolated marginal plates. The upper marginals are convex, encroaching more or less on the upper side of the disk, usually spinulose, sometimes almost granulose, and often with one or two superior spines or tubercles. Lower marginals spinulose and spinose, prolonged actinally, most of them reaching the adambulacral plates; but one or two interradial pairs may not reach the adambulacral plates, and in that case one or two pairs of small adoral interactinal ossicles may intervene, but these do not form regular rows, nor an important triangular area. The species having an important group of actinal plates are here separated as a genus, *Astropectinides.* The lower marginals are closely spinulose and fasciolated laterally. Adambulacral plates about equal in number to lower marginals, the inner end angular. They have a horizontal group of about three furrow-spines and a divergent stellate group on the actinal side, often with the central spine enlarged. The papulæ stand singly around the dorsal paxillæ, generally absent along the median line. Dorsal pore usually lacking, sometimes present. Superambulacral plates well developed. Pedicellariæ generally lacking.

ASTROPECTEN SIDEREALIS Verrill, sp. nov.

Plate l, figure 6 (details).

Astropecten armatus Fisher (*non* Gray), op. cit., 1911*b*, p. 56, pl. v, figs. 1, 2; pl. vii, figs. 3, 6; pl. l, fig. 4; pl. li, fig. 3.

A variable species. The type has the following characters: Disk of moderate size, thick; rays five, rapidly tapered, acute. Radii, 14 mm. and 58 mm.; ratio, 1 : 4.15.

The upper marginal plates are short, convex, prominent, their upper ends rising above the level of the abactinal paxillæ. They are separated by rather wide and deep fasciolated grooves; those in the interradial angles are externally wedge-shaped, with the sutures vertical, but distally the sutures become oblique and the plates scarcely wider than long. Most of their outer surface is closely covered with small, rounded or hexagonal granules, which grade

into the small spinules of the fascioles on the sides. At the summit of more or less of the proximal plates there is a small, nipple-shaped or thimble-shaped spine, which is liable to be broken off, leaving a small, pit-like scar.

The dorsal paxillæ bear small, regular, stellate groups of short, somewhat unequal, clavate or capitate spinules. In the larger ones there is usually a central, larger, capitate spinule, surrounded by a circle of about six to eight smaller ones; these are surrounded by a marginal circle of about ten to fifteen of about the same size.

The lower marginal plates are strongly spinose; most of the surface is covered with small, flat, more or less imbricated spinules. There is a submedian row of six to eight unequal, roundish, acute spines, increasing in size outwardly, the last, or next to the last, being much the largest, stout and acute, not much flattened; sometimes there is a smaller slender one above the largest.

Adambulacral plates have a convex inner or furrow-group of about four slender spines, of which the innermost is larger, longer, angular, and stands in front of the others. On the actinal side there is a central, erect, unusually large, flat, blunt or truncate, often grooved spine, and back of this a row of three or four much smaller spines, of similar shape, on the outer and proximal margins of the plate.

The adoral and epioral spines are very numerous, short, stout, obtuse.

It varies greatly in the length and sturdiness of the rays, in the size of the superomarginal plates, and especially in the number and form of the tubercles or spines on the superomarginal plates. These may be reduced to a single imperfect series of small tubercles, or there may be one continuous series, or two imperfect series—rarely two nearly complete series. They may be lacking proximally and present distally, or vice versa. Sometimes they become spine-like, especially the outer ones; but more often they are short, stubby cones or blunt tubercles. Other parts also vary. Generally, however, the enlargement of the central spinules of some of the paxillæ, the differentiation of the paxillæ along the median line, and especially the scale-like, flattened, inferomarginal spinelets, remain pretty constant.

This species, in form and general appearance, resembles *A. ærstedii* Lütken, of Central America, which is now generally considered identical with the true *armatus* of Gray. This resemblance is due in large part to the character of the marginal spines in the interradial

regions, and the size and form of the marginal plates. The easiest distinctive mark is, perhaps, the flattened and imbricated condition of the inferomarginal spinules.

I have compared it with a type-specimen of *ærstedii,* received from Dr. Lütken himself. The upper marginal plates in the latter have two small spines; the dorsal paxillary spinules are longer; the lower marginal plates have two distinct rows of larger spines, and the small spinules are more slender and not imbricated, nor flat and scale-like; the adambulacral spines are similar, but more slender, especially the larger central spine of the actinal side, which is, also, less flattened.

This species is allied to *A. californicus,* but has coarser paxillary spinules, with a larger central one, and different spinules on the marginal and adambulacral spines. The latter never has spines or tubercles on the upper marginal plates.

Near San Francisco (Prof. W. E. Ritter). Type in Yale Museum.

Professor Fisher (op. cit., 1911*b*, p. 60) has given a number of localities for this species, under the name *A. armatus.* They range from off San Pedro and Long Beach, California, to San Diego, in 4 to 130 fathoms. He considers that its range extends to Panama and Ecuador (as *armatus*), but I consider the southern form distinct.

VARIATIONS.

Professor Fisher has given a detailed description and several figures of this species, and has very fully discussed its variations. Therefore it is not necessary to give many details here. The above description was written in 1904, long before his paper appeared, and was based on a rather average specimen, as the type.

ASTROPECTEN CALIFORNICUS Fisher.

Plate L, figure 5 (details); plate C, figure 1; plate CI, figures 1, 2; plate CII, figures 1, 2.

Astropecten californicus FISHER, op. cit., 1906, p. 299; op. cit., 1911*b*, p. 61, pl. VI, figs. 1, 2; pl. VII, fig. 1; pl. L, fig. 5; pl. LI, figs. 2, 2*a*.

Disk small, but rather thick; rays five, long, rather narrow, regularly tapered, acute. Radii, 17 mm. and 77 mm.; ratio, 1 : 4.5.

Upper marginal plates numerous, not very wide, nor much encroaching on the dorsal surface, convex, separated by deep fasciolate grooves, without special spines, but covered with unequal small spinules, of which those in two or three rows along the middle are a little larger and capitate or like rounded granules, while the rest are longer, slender and blunt.

The dorsal paxillæ are small, even, and much crowded, with regularly stellate, small, short, clavate spinules, of which there may be ten to fourteen marginal and five to eight central ones on the larger paxillæ. On the center of the disk the paxillæ become smaller and very much crowded, so that they seem to blend together. On the bases of the rays they are about 1 mm. to 1.2 mm. broad.

The inferomarginal plates are large and very spinose; they bear two submedian rows of acute spines, increasing in size upward, the upper two or three being much larger and longer than the rest, and on the basal plates they rapidly increase in size and become flattened, somewhat paddle-shaped, with acuminate tips. The rest of the surface is covered with numerous small, somewhat imbricated and flattened, blunt spinules.

The adambulacral plates have a furrow-series of three or four rather long, slender, divergent spines; and on the actinal side four, or sometimes five, much larger, flattened or paddle-shaped, obtuse, erect spines, usually standing two by two. The central spine of the furrow-series is stouter than the others, but stands a little farther within the groove.

No pedicellariæ were found.

Off San Francisco (Prof. W. E. Ritter); Pacific Grove (Prof. W. R. Coe). This species has a known range from Monterey Bay to Lower California.

Dr. Fisher records it from numerous stations, from off Monterey to Guadalupe Island, in 10 to 244 fathoms. Abundant off Monterey; off San Pedro; off Santa Barbara, etc., in 25 to 50 fathoms.

ASTROPECTEN ORNATISSIMUS Fisher.

Astropecten ornatissimus FISHER, op. cit., 1906*b*, p. 119; op. cit., 1911*b*, p. 67, pl. VI, figs. 3, 4; pl. VII, fig. 2; pl. LI, figs. 1-1*c*.

Allied to *A. californicus*. Differs in having larger dorsal paxillæ, with longer, more slender, and more spaced spinules; in having the paxillæ more uniform in size across the ray, not more elongated medially, nor smaller over a large central area, of the disk; in having more slender, longer and more tapered adambulacral spines; in having the upper edge of each ambulacral plate produced into a thin lamina between the pairs of ampullæ, with its edge serrulate.

Greater radius, 56 mm.; lesser, 14 mm.; ratios, 1 : 4 (Fisher).

I have not received this species. Mr. Fisher records it from sixteen stations from off San Pedro and Catalina Island, to Guadalupe and Cerros Islands, Lower California, in 47 to 207 fathoms.

Genus **Astropectinides** Verrill, nov.

Type, *A. mesacutus* (Sladen), as *Astropecten.*

This genus is proposed for those species, usually referred to *Astropecten,* which have a well developed triangular actinal area, covered with two or more rows of interactinal plates parallel with the adambulacrals and corresponding to them in radial length. The proximal inferomarginal plates are correspondingly abbreviated, not prolonged nearly or quite to the jaws, as in *Astropecten.* The dorsal paxillæ and upper marginal plates are as in *Astropecten.*

Several species, described as *Astropecten,* besides the type, belong to this genus. Among them are *A. callistus* (Fisher) and *A. ctenophorus* (Fisher), Hawaiian Islands. The genus is extralimital.

The type, *A. mesacutus* Sladen (1883; and op. cit., 1889, p. 219, pl. XXXIV, figs. 5, 6; pl. XXXVIII, figs. 7-9), has twenty to thirty spinulose plates in each interradial area. It is from the Antarctic Ocean and the South Atlantic, in 44 to 90 fathoms.

Genus **Bunodaster** Verrill.

Plate LXXXVI, figures 1, 1*a;* plate CIV, figures 1, 1*a;* plate CV, figures 1, 1*a.*

Bunodaster VERRILL, Amer. Naturalist, XLIII, p. 554, fig. 4, September, 1909. Fisher, op. cit., 1911*a*, p. 164; 1911*b*, p. 40.

Superficial appearance much as in some dorsally unarmed species of *Astropecten,* but with smaller marginal plates.

Form stellate with elongated rays. Dorsal surface covered with low, convex, somewhat hemispherical plates, which are of the nature of parapaxillæ, with enlarged, somewhat lobed or stellate concealed bases, the lobes slender and articulated, with single papulæ between them. The surface of the outer boss, or raised part, is covered with numerous small, slender, divergent, spinules, which form simple, deep fascioles at the margins.

Marginal plates not very thick, convex, all closely spinulose and the lower ones spinose; the upper ones are rather small, in the interradial arcs, where the lower ones are not much prolonged adorally, but end abruptly against a triangular area of fascioled and spinulose actinal plates, which are flattish or convex and form rows parallel with the adambulacrals, or three V-shaped rows with two odd interradial plates in line. The adambulacral plates are the same in length as the synactinals; they have a horizontal furrow-group of three or four spines and an actinal divergent group of similar ones.

Fasciolated grooves extend between the adambulacral and most of the interactinal plates. Jaws are very prominent on the actinal surface and bear numerous peroral and adoral spines on the sides and summit. The lateral peroral spinules are fasciolated; the actinal groups or rows are connivent.

This genus is undoubtedly closely allied to *Blakiaster, Persephonaster* and *Leptychaster,* especially to the two former.

Dr. Fisher thinks (op. cit., 1911*b*, p. 40) that it ought to be united with *Blakiaster,* which he carefully describes from the type. I have also studied the same type. It differs from that genus, however, in the less massive and differently shaped marginal plates, which are less complex and have more fully developed fascioles. The lower marginals have the spines in a central row or group, not submarginal. There is no differentiated median radial series of dorsal ossicles; nor any notable number of secondary ossicles, so evident in *Blakiaster;* nor any median radial area destitute of papulæ, as in the latter. There are well defined fascioles between the adambulacral and interactinal plates, not found in the latter; and the adoral adambulacral spines are deeply sunken in the groove, as in *Persephonaster,* but not in *Blakiaster* (type, *B. conicus* Perrier).

The abactinal plates are thinner, more regularly stellate, and more delicately articulated by the slender radial lobes than in the latter, so that the test is more flexible. In *Blakiaster* the lobing is irregular and the edges overlap.

In many of these characters it is nearer to *Persephonaster,* but the latter lacks the odd interradial interactinal plates, found in this genus and in *Leptychaster.*

From the latter it differs in the characters of the abactinal ossicles, in the less profoundly fasciolated grooves between the marginal plates, and in other characters; but it is perhaps as nearly allied to the latter as to *Blakiaster.*

It is, in fact, a sort of connecting-link between these three genera. Possibly it may eventually be desirable to unite it with *Leptychaster* and *Blakiaster* in one larger genus, should more connecting species be discovered.

BUNODASTER RITTERI Verrill.

Plate LXXXVI, figures 1, 1*a* (details); plate CIV, figures 1, 2 (type); plate CV, figures 1, 1*a* (type, enlarged); text-figures Nos. 15, 16.

Bunodaster ritteri VERRILL, op. cit., XLIII, p. 554, fig. 4, 1909.

Rays five, regularly and rapidly tapered, slender, subacute; neatly stellate. Disk rather thin, flat, about as wide as the length of the

rays, with broadly curved interradial margins. Radii, 10 mm. and 32 mm.; ratio, 1 : 3.2.

Upper marginal plates regular, not very large, a little convex, narrow and encroaching very little on the dorsal side in the interradial angles, but on the rays becoming more conspicuous, as seen from above, slightly oblique, squarish. The two rows at the middle of the ray are separated by a space only about equal to the width of a plate; they are regularly and uniformly and closely covered by small, erect, divergent, blunt, rough spinules, and separated by narrow, deep, finely fasciolated grooves.

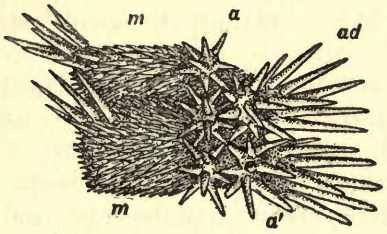

FIG. 15.

Bunodaster ritteri Verrill, type. Portion of under side of a ray; *ad*, adambulacral spines; *a*, *a'*, two rows of interactinal plates and spines; *m*, *m*, two inferomarginal plates and spines enlarged.

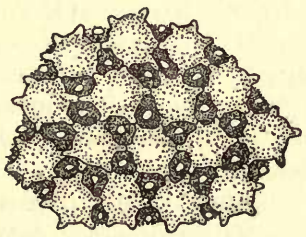

FIG. 16.

Bunodaster ritteri Ver., type. A group of dorsal plates and papular pores from middle of the base of a ray, seen from the inside, much enlarged.

The dorsal surface is covered with rather large, round, mostly equal, convex, stellate paxillæ, each covered with a large number of regularly divergent, small, nearly equal, obtuse, rough spinules, of which the larger have from twenty to thirty. Those at the margins form simple, deep fascioles. When the spinules are removed, the plates are in the form of low, round-topped or nearly hemispherical bosses, mostly nearly equal in size and form, with only a few smaller ones, here and there, and separated by intervals of flexible integument, with about six papulæ standing singly and regularly around each plate. The papulæ are lacking on a small central area of the

disk and on a small triangular interradial area close to the marginals, where the ossicles are more closely joined. They occur regularly on the rest of the disk and on the entire breadth of the rays, except distally, near the tips. There is no median radial band of ossicles differing in size or form from those adjacent and not surrounded by papulæ, as is the case in *Blakiaster*.

Seen from the inner side, the dorsal ossicles are all alike, except for a few rather smaller ones, and lie in one plane. Their inner or basal portion is roundish, mostly with six slender, radiating lobes; or they may be called six-rayed stellate. They are articulated only by the slender ends of these radial lobes, which ordinarily do not show at all on the outer surface. The papular pores are between the radial lobes.

The inferomarginal plates are short in the radial direction, in the interradial arcs, scarcely exceeding the upper ones, wedge-shaped, thick below. Towards the middle of the rays they become a little oblique, nearly as wide as long, somewhat rhombic, near the tips of the rays they become small, apple-seed shaped, and imbricated obliquely. They are covered with small spinules; like the upper ones, and mostly bear a small cluster, or short median row, of three or four small, slender, acute spines, much longer than the spinules.

The triangular interradial areas, below, are flattened, with a pavement of slightly convex, roundish plates, mostly in three pairs of divergent rows parallel with the ambulacra; they are covered with stellate groups of numerous spinules, like those of the marginal plates, but rather longer. An odd interradial plate lies between the ends of the second and third rows.

The adambulacral plates have a convex marginal series of about four rather long, slender, divergent spines; and one actinal divergent or stellate group of about six to eight smaller and more slender spines.

Epioral spines small, slender, and very numerous, in two large series. Perorals a little stouter.

Apical oral spines four, rather stout, high up on the jaws and nearly concealed by the adjacent epiorals. The adoral adambulacral spines are deep within the grooves, opposite the large and prominent jaw-plates, on the edges of the strongly compressed adoral plates, forming a nearly simple curved row.

When the epioral spines are removed, the two prominent ridges of the actinal face of the jaw-plates are closely united, forming a conspicuous, elevated, narrowly elliptical carina.

The terminal or ocular plate of the rays is relatively large, thick, trapezoidal, longer than wide. It is reached by about two or three rows of very small dorsal plates.

No pedicellariæ were found.

Off San Francisco (Prof. W. E. Ritter). Only one specimen seen.

Genus **Leptychaster** Smith.

Leptychaster Smith, Ann. and Mag. Nat. Hist., ser. 4, xvii, p. 110, 1876.
Leptoptychaster Smith, Phil. Trans. Roy. Soc., Zoöl., clxviii, p. 278, 1879.
? Parastropecten Ludwig, Mem. Mus. Comp. Zoöl., xxxii, p. 76, 1905.
Leptychaster (*pars*) Fisher, op. cit., 1911*b*, p. 42.

Stellate, with five short rays, rarely six; disk broad.

Marginal plates, thick, oblique, at least distally, the upper ones often smaller than the lower and not encroaching much on the abactinal side, proximally; prominent or carinate in the middle, with wide and deep fasciolated grooves between them; covered with small spinules, which become larger in the grooves. Dorsal plates are true paxillæ, with roundish or somewhat stellate bases, in the papular areas; their spinelets are usually very small and numerous.

The interactinal plates form an important triangular area. They are spinulose, thick or carinate, with deep fasciolated grooves between them. They are arranged in transverse rows running to the adambulacral plates; or they may be said to be in rows parallel with the ambulacra, with a few unpaired interradial plates. The transverse rows of interactinals nearly correspond in number to the marginals, except in the middle of the interradial areas, where there are more. The adambulacral plates have a group of slender furrow-spines and a divergent group of similar ones on the actinal side.

Dr. Fisher thinks that *Parastropecten* Ludwig and *Glyphaster* Verrill should be united with *Leptychaster*.

The discovery of *L. pacificus* and other somewhat intermediate forms renders this view somewhat reasonable. It would seem, however, that *Glyphaster* can be retained at least as a subgenus, if not a genus, for those species which, like *anomalus,* have robust and squarish upper marginal plates, and the abactinal plates of the papular areas only slightly lobed. The inferomarginal plates are not oblique in the latter, and each corresponds to two rows of interactinals instead of one.

Whether *Parastropecten* Lud. is strictly synonymous with *Glyphaster* is uncertain. The type is *P. inermis* Lud.

The type of *Leptychaster* is *L. kerguelenensis* Smith, from the Antarctic. In a later paper he used a revised spelling of the word

(*Leptoptychaster*), which has been adopted by Sladen and many other writers. The change seems to be uncalled for and pedantic.

The type species is known to carry its eggs and young on the back, under the paxillary spines. This has not been observed in either of the northern species.

LEPTYCHASTER ARCTICUS (Sars) Sladen.

Astropecten arcticus M. SARS, Reise Lofoden og Finmarken, Nyt Mag. Nat., VI, p. 161, 1851.
Archaster arcticus VERRILL, Amer. Journ. Sci., XVI, p. 214, 1878.
Leptoptychaster arcticus, var. *elongatus* SLADEN, op. cit., p. 189, 1889.
Leptoptychaster arcticus SLADEN, op. cit., p. 189. Verrill, Proc. Nat. Mus., XVII, p. 255, 1894; Amer. Journ. Sci., XLIX, p. 133, 1895. Ludwig, Fauna Arctica, I, p. 452, 1900.
Leptychaster arcticus FISHER, op. cit., 1911*b*, p. 43, pl. VIII, fig. 1; pl. IX, fig. 4.

This well-known Arctic and North Atlantic species has been recorded from the North Pacific by Fisher. It differs from the other west coast species in having more slender rays (radial ratio, about 1 : 3.25) and smaller superomarginal plates, about forty on each side of a ray, which form only a narrow margin to the disk. The inferomarginals are quite oblique and have a narrow carina-like ridge and wide fasciolate furrows. Dr. Fisher has given a detailed description of North Pacific specimens.

In the North Pacific, according to Fisher, it ranges from Bering Sea to Yezo, Japan, in 72 to 107 fathoms.

On the eastern coast of North America it is most frequent in 80 to 200 fathoms. Its recorded ranges in depth are from 50 to 965 fathoms (1350 fathoms, Sladen).

It was taken by the U. S. Fish Commission parties at twenty-three stations, from N. lat. 45° 14′ to 38° 29′. It always occurred in small numbers. It is found off the northern coasts of Europe, south to Norway and off Ireland, and northward to the Arctic Ocean and Barents Sea. It is evidently circumpolar.

LEPTYCHASTER PACIFICUS Fisher.

Plate LXXIV, figure 5.

Leptychaster pacificus FISHER, Proc. Wash. Acad. Sci., VIII, p. 112, 1906; op. cit., 1911*b*, p. 45, pl. VIII, fig. 2; pl. IX, fig. 2; pl. L, figs. 1, 1*a*.
Leptychaster millespina VERRILL, op. cit., 1909, p. 553.

Form regularly stellate, with five tapering, acute rays. The radii, in the specimen here described, are about 14 mm. and 35 mm.; ratio, 1 : 2.5; often 1 : 3.

It resembles *L. arcticus* of the North Atlantic in form and size, but is a more robust species, with thicker disk and rays and larger and fewer marginal plates.

The marginal plates are about twenty-two on each side of a ray, finely spinulated, prominent, the lower ones projecting beyond the upper ones, and separated from them by a deep groove; they become somewhat oblique distally. The fasciolate grooves between the plates are deep and often nearly as wide as the ventral plates, proximally. The lower marginal plates are high, compressed, wedge-shaped. The dorsal paxillæ are small, close, and covered with numerous fine, slender spinules. When the spinules are removed the columns are small, unequal, round, slender, with small capitate tips.

The actinal plates are prominent, subimbricated, with deep grooves between; their summits are oblique, elliptical, covered with numerous elongated, slender spinules.

The adambulacral plates project into the grooves, which are very narrow, and have deep fasciolate notches between them. They bear a furrow-series of about five or six small, slender, subequal, rather short spines, and an actinal group of about nine smaller, divergent spinules. No pedicellariæ were found. Madreporite is small and sunken between the paxillæ.

The two specimens here described were taken at Departure Bay, British Columbia, by C. H. Young, 1908 (Canadian Geological Survey). Unalaska to Straits of Georgia (Fisher), in 56 to 238 fathoms.

Although this species resembles *L. arcticus* of the North Atlantic, it is quite different in some respects. The adambulacral spines of the latter are larger, fewer, much more unequal; the spinules of the marginal plates and dorsal paxillæ are coarser; the marginal plates smaller, less prominent and more numerous, about forty to forty-four, while in this, when adult, they are from twenty-two to about thirty-five. The specimen figured was the type of *L. millespina* Verrill.

Genus **Glyphaster** Verrill.

Glyphaster Verrill, Amer. Naturalist, xliii, p. 553, 1909. Fisher, op. cit., 1911*b*, pp. 39, 53.

Disk broad; rays very short. Marginal plates thick and squarish, scarcely oblique. The upper ones encroach on the upper surface. Each inferomarginal corresponds to two adambulacrals on the rays, and nearly three in the interradial areas. The marginal plates are

covered with fine spinules. The inferomarginal plates are convex, not carinated. The dorsal plates are finely spinulated paxillæ. Adambulacral plates much as in *Leptychaster*.

Professor Fisher (op. cit., 1911*b*) does not recognize this as a distinct genus.

GLYPHASTER ANOMALUS (Fisher) Verrill.

Plate I, figures 1, 2; plate VI, figures 1, 2.

Leptychaster anomalus FISHER, 1906, p. 115; 1911*b*, p. 48, pl. VII, fig. 4; pl. IX, fig. 1; pl. L, figs. 2, 2*a*.

Glyphaster anomalus VERRILL, op. cit., 1909, XLIII, p. 554.

The stout inferomarginal plates on the disk and rays correspond each to two adambulacrals, except the first pair, each of which is connected with three adambulacrals by lines of interactinal plates. But in *L. arcticus* each inferomarginal corresponds pretty closely with a single adambulacral, except the two proximal interradials, each of which is connected with two adambulacrals by lines of interradials.

The sutures between the inferomarginals are straight and distally nearly at right angles to the furrows, while in *L. arcticus* they are all oblique, and distally very oblique and curved, with the inner end turned adorally, so that the corresponding adambulacral is about opposite the outer end of the preceding marginal.

The epioral side of the jaws is elevated and laterally compressed, narrower aborally, and the two halves are close together, leaving a narrow, strongly fasciolated groove between them, while in *L. arcticus* they are not so prominent, elliptical, with no distinct fasciolated groove.

Bering Sea, off Pribilof Islands and St. Paul, to southern Alaska, and to Japan, in 32 to 688 fathoms; off Monterey, California, in 871 fathoms (Fisher).

Family *PORCELLANASTERIDÆ* Sladen.

Porcellanasteridæ SLADEN, 1886; Voy. Chall., XXX, p. 125, 1889. Fisher, op. cit., 1911*b*, p. 22.

Disk usually broad, with short rays and high margin. Marginal plates usually paired (inferior ones are sometimes abortive), thin, usually covered with strong membrane, seldom granulose, sometimes with spines; edges commonly fasciolated, or there may be special fasciolated or cribriform organs.

Dorsal ossicles either paxilliform, or simple plates with a single spinule. Interactinal plates flattened, imbricated. Adambulacral armature simple, uniserial. Ampullæ single. No intestine. Dorsal pore generally absent. Superambulacral plates usually absent.

The stomach is very large; the food consists of fine mud or sand containing foraminifera, etc., which these starfishes swallow in large quantities. Hence they are best adapted to life on bottoms of "Globigerina ooze," in the deep seas.

This family was divided by Sladen, 1886, into two subfamilies: Porcellasterinæ and Ctenodiscinæ.

PORCELLASTERINÆ Sladen.

In these there are special localized cribriform organs. No fasciolated channels between the interactinal plates. Superambulacrals always or nearly always lacking. All are confined to deep water.

CTENODISCINÆ Sladen.

In these there are simple fasciolated channels between the interactinal plates and continuous with more definite ones between the marginals, covered by small, flat spinules. (See pl. v, figs. 6-8*a*.) Dorsal plates are paxilliform. Superambulacrals are present.

Subfamily *CTENODISCINÆ* Sladen.

Ctenodiscinæ (subfamily of *Porcellanasteridæ*) SLADEN, op. cit., 1886; Voy. Chall., XXX, pp. 127, 170, 1889.

Disk broad, flat, with short rays. Marginal plates thin, covered with membrane, not granulose, paired and conterminal, in two closely united rows, furnished laterally with specialized fasciolate grooves, covered by a single row of flattened spinelets. Disk usually with true paxillæ; paxillar columns enlarged at base, but isolated. Actinal interradial areas covered with flat plates, with fasciolated grooves between the rows or double rows, continuous with those between the marginal plates and adambulacral plates.

An unpaired interradial marginal plate, in each series, is present in *Pectinodiscus* Ludwig; also an odd row of actinal plates.

Adambulacral plates with a divergent group of furrow-spines, and some on the actinal side. A minute central dorsal pore, often on an elevation.

At present this subfamily includes only *Ctenodiscus* and *Pectinodiscus* Ludwig. It is nearly intermediate in many respects between

Porcellanasterinæ and some of the Astropectinidæ, especially *Leptychaster*. From the latter it differs in the somewhat more specialized fascioles of the marginal and actinal plates, and their thinner structure and naked central portions. From the Porcellanasterinæ the differences seem important. The latter have much more specialized fascioles, in special locations on the margin, with none between the actinal plates, and usually lack regular dorsal paxillæ. Like the latter, it has single ambulacral ampullæ.

Genus **Ctenodiscus** Müller and Troschel.

Ctenodiscus MÜLLER and TROSCHEL, Syst. Ast., p. 76, 1842. Sladen, op. cit., p. 170, 1889. Fisher, op. cit., 1911*b*, p. 31.

Stellate with nearly vertical margins. Actinal plates thin and flat, without granules; covered with membrane; the principal ones united in double radial rows, each double row corresponding to a single marginal plate and to two adambulacral plates. Thus the fasciolate grooves run between the double rows (or alternate single rows). But distally, on the rays, the adambulacral and marginal plates correspond, plate for plate.

Dorsal ossicles are true paxillæ. The upper marginal plates are high, thin, nearly vertical, and proximally form a narrow margin, usually with a small spine to each plate; but distally they encroach upon the upper side of the rays.

The central dorsal area often has a more or less conical elevation of the dermis, covered with paxillæ like the adjacent parts, but finer. It is more prominent in the young, and when the stomach is filled with soft mud, as is usually the case when living.

The northern and arctic species (*C. crispatus*) is circumpolar. Two closely allied species or varieties are found in Antarctic waters, one on each coast of southern South America. Dr. Fisher thinks that they may not be distinct from *C. crispatus*.

CTENODISCUS CRISPATUS (Retz.) Düben and Koren.

Plate v, figures 6, 7, 8, 8*a* (details); plate XLIX, figures 5, 5*a* (details).

Asterias crispatus RETZIUS, Dissert. Asteriarum, p. 17, 1805.

Ctenodiscus polaris and *C. pygmæus* MÜLLER and TROSCHEL, Syst., pp. 76, 129, pl. v, fig. 5, 1842.

Ctenodiscus crispatus DÜBEN and KOREN, K. Vet. Akad. Handl., p. 253, 1844. Stimpson, Invert. G. Manan, p. 15, 1853. Lütken, Grönl. Echinod., p. 45, 1857. Verrill, Proc. Bost. Soc. Nat. Hist., x, p. 345, 1866; Amer. Naturalist, XLIII, p. 548, 549, figs, 3, *a*, *b* (4-rayed and 5-rayed), 1909.

Ctenodiscus corniculatus PERRIER, Stell. du Mus., p. 380, 1875 (after Linck). Duncan and Sladen, Echinod. Arctic Sea, p. 49, pl. III, figs. 17-20, 1881. Sladen, Voy. Chall., p. 171, 1889. Döderlein, op. cit., p. 221, pl. IX, figs. 2, 3, 1900.

Ctenodiscus krausei LUDWIG, Zool. Jahrb., Syst., I, p. 290, pl. VI, figs. 13-16, 1886.

Ctenodiscus crispatus FISHER, op. cit., 1911*b*, p. 31, pl. III, figs. 1-4; pl. IV, figs. 1-6.

The following description is from Alaskan specimens. Disk broad, thin, with regularly curved interradial margins, which are bordered by the summits of the thin upper ends of the upright superomarginal plates, each of which usually bears a small conical spine.

Rays five (rarely four), broad at base, rapidly tapered, subacute, varying considerably in length, relative to disk. Radii of a specimen from off Chilikoff, Alaska, are 14 mm. and 24 mm.; ratio, 1 : 1.7.

Another, from the same place, has the radii 12 mm. and 23 mm.; ratio, 1 : 1.9. These are of medium proportions; the ratios of the radii are often 1 : 2, and up to 1 : 2.25.

The dorsal paxillæ are minute and pretty uniformly crowded over the whole surface. Madreporite rather large and conspicuous. Ocular plate rather large, shield-shaped, longer than broad, distal end notched.

The upper marginal plates are closely united to the lower ones, end to end, so that the fascioles between them coincide; those in the interradial areas extend but slightly on the disk, but the small distal ones encroach considerably on the upper side of the rays. The marginal spine is short, subacute, articulated on a central mammilliform tubercle, which shows a central pit when the spine is removed. The tubercle is wider than the median naked keel of the plate, except distally on the rays, where the keel becomes wider. The fasciolated spinules are longer than the width of the keel, except distally on the rays; they are flat, and project at nearly right angles to the edges of the keel and parallel to the surface of the plate; they form a single regular close row, with a small, well defined channel under them. This channel extends down between the inferomarginal plates, with the same sort of fasciolated spinules; but the latter gradually become shorter downward, and point obliquely upward.

The inferomarginal plates of the interradial arcs are considerably shorter, vertically, than the upper ones, and have the naked median keel more than twice as wide, while toward the ends of the rays it becomes much wider, covering most of the squarish plates, the

fasciolated spinules becoming very short. These distal plates have a slightly granular surface, but no articulated granules. Most of the inferomarginals bear a small, subacute, articulated spine or tubercle near the upper end.

The actinal plates, in specimens of ordinary adult size, form six double rows,[1] running from the six interradial inferomarginal plates to twelve adambulacral plates. The plates are small next the marginals, but become much larger toward the adambulacrals; they are smooth, flat, irregularly angular, with rounded corners, and alternate closely in the two rows, without intervening grooves or spinules; their united edges overlap slightly.

Sometimes there are slight irregularities in this arrangement; the more distal of the double rows may correspond with but one adambulacral, on some of the rays. Farther out the marginal and adambulacral plates correspond, and there are but two (or only one) actinal plates between them. Beyond the sixth marginal, the remaining five or six are joined directly to the adambulacrals.

The fasciolated grooves run directly from between all the inferomarginal plates to the ambulacral grooves, thus passing between the double rows of actinals; and distally between all the marginals and adambulacral plates. They are bordered by regular, close, single rows of short appressed spinules.

The adambulacral plates are large and have a strong triangular lobe projecting into the grooves, ending in line with a sharp ridge that stands between the large ambulacral feet. The proximal plates bear a series of three or four (sometimes five) acute, divergent furrow-spines; the distal ones, only two spines; on the actinal side there may be three to five small spines, mostly marginal. Oral spines numerous, the two medial adorals stouter.

Color, light yellow to pale orange, the upper surface often gray when the stomach is distended with mud, as it frequently is.

The median dorsal nephridial cone is usually low in the adults, but elongated in the very young ones. The central pore is minute.

I have studied a considerable number of regular four-rayed specimens taken off the coast of New England by myself and by the U. S. Fish Commission.

This species is abundant in the North Atlantic and Arctic Oceans, on soft muddy bottoms, in from 10 to 650 fathoms. It is found on

[1] The detailed figure of these plates, given by Müller and Troschel, is incorrect, as to their regular arrangement in double and single columns. (See pl. XLIX, fig. 5, copied from Müller and Troschel, and pl. v, fig. 6.)

the east American coast from Greenland south to Cape Cod in shallow water, and in deep water to the latitude of Cape Hatteras. Particularly abundant in the Gulf of Maine and Massachusetts Bay, in 20 to 100 fathoms, where several hundreds are often taken at one haul of the dredge. It is also common on the northern coasts of Europe, south to Norway and the Faroe Islands. I have seen a number of specimens from northern Alaska. Off Chilikoff (Professor Kincaid), described above, and from Vancouver Island.

C. krausei Ludwig was described from two small specimens from Bering Sea. Both specimens had the larger radius 18 mm; lesser, 9.5 mm. Subsequently Ludwig himself referred them to *C. crispatus*. According to his figure (see pl. v, fig. 6), they differ from those described above in having only two double columns of actinal plates in the interradial areas, due, perhaps, to immaturity.

Fisher records it from numerous localities in the North Pacific, mostly from Bering Sea and off Alaska, southward to California, in 31 to 1033 fathoms, and off the Asiatic coast to Japan. Off Gulf of California and Panama (Ludwig). Dr. Fisher also believes that the forms described from off the two coasts of southern South America as *C. australis* and *C. procurator,* by Sladen, are not distinct. If this be true, its range would be greatly extended.

It is a very variable species, if all the forms belong to one species.

Family *LUIDIIDÆ* Verrill.

Luidiidæ VERRILL, Trans. Conn. Acad., x, p. 201, 1899. Fisher, op. cit., 1911*b*, p. 105.

Luidiinæ (subfamily) SLADEN, op. cit., pp. 175, 244, 1889.

Disk small, covered with true paxillæ, which are usually largest at the sides of disk and rays; rays five to ten or more, long, flat, flexible in life; upper marginal plates small, paxilliform or indistinguishable; lower ones large, spinose, fascioled, corresponding in number and length with the adambulacrals and separated from them throughout the rays by a small peractinal plate.

The dorsal nephridial glands, or "cœcal appendages," intestine and dorsal pore are lacking; the superomarginal plates are small, usually not easily distinguishable. The papulæ are branched.

The gonads are multiple and arranged in rows, with separate pores along the sides of the rays.

Pedicellariæ usually present on the actinal side, usually forceps-like, with two or three blades, or spiniform.

Ambulacral feet large, flattened, muscular; can be used as paddles for gliding rapidly along the bottom or just under the surface of sand or mud.

This family seems eminently worthy of separation from Astropectinidæ. Its whole structure is adapted to its life under the surface of sand or mud, and for rapid motion. I have observed that *Luidia clathrata* (see pl. CIII, fig. 1) swims or paddles with remarkable speed, just under the surface of the sand in shallow water, and that it swims or glides actively in an aquarium, by using its feet as paddles. (See p. 7.)

Genus **Luidia** Forbes.

Luidia FORBES, Wern. Trans., 1839, p. 14; Mem. Wern. Soc., VIII, p. 128, 1840. Müller and Troschel, Syst. Aster., p. 77, 1842. Sladen, op. cit., p. 244, 1889. Fisher, 1911*b*, p. 105.

Rays five to ten, rather flat, flexible. Dorsal columnar paxillæ have lobate, articulated bases; summits either plainly paxillose or with a central spine or tubercle (spinopaxillæ), or with both kinds; largest next the lateral borders of the rays. Inferomarginal plates spinose and spinulose. Pedicellariæ often absent; when present, forceps-like, with two or three blades or valves. They are usually situated on the adambulacral plates; sometimes on the inferomarginals or peractinals.

Inferomarginal plates transversely elongated, with wide and deep fasciolated grooves between them, bordered by slender spinules; central portion with one or more rows of spines. Superomarginals small, paxilliform, rounded. Adambulacral plates short, with one furrow-spine (rarely two); they are separated by wide grooves. The dorsal paxillæ may be quadrate at surface and crowded, in regular rows, or stellate. Regular rows of papulæ between the rows of paxillæ. No superambulacral plates observed.

LUIDIA FOLIOLATA Grube.

Plate C, figures 2, 2*a*; plate CIII, figure 2; plate CV, figure 2.

Luidia foliolata GRUBE, op. cit., Breslau, XLIII, p. 69, 1866. Fischer, op. cit., 1911*b*, p. 106, pl. XIX, figs. 1-3; pl. XXI, figs. 3-5; pl. LIV, fig. 3.

This species grows to large size on the California coast. One from British Columbia has the radii 25 mm. and 205 mm.; ratio, 1 : 8.2. Another has the radii 18 mm. and 130 mm.; ratio, 1 : 5.5. The rays are rather flat proximally, gradually tapered to slender tips.

The paxillæ form regular longitudinal and transverse rows. Those next the margin are rather quadrate superficially; the central ones are small, crowded, roundish, stellate; all have flat or slightly convex summits. The larger are 1 mm. to 1.25 mm. broad; they have a central rosette of small clavate or capitate spinules, of which one, or sometimes two, stand at the center and six or eight around it; outside of this is a marginal horizontal fringe of longer and more slender spinules, twelve to fifteen or more in number, making fasciolated spaces. When the spinules are removed, the paxillary column has a somewhat enlarged, roundish or oblong-elliptical summit; the base is regularly four-lobed; the lobes are carinate and articulated movably. Between the rows, alternating with the paxillæ, are regular rows of large papular pores. Proximally there are, on each side, about five or six rows of paxillæ.

The upper marginal plates are paxilliform and similar to the adjacent paxillæ, but closely joined to the upper end of the inferomarginals; distally they become relatively larger.

The inferomarginal plates are large and prominent, their upper ends defining the margin. Each bears about three to five principal spines, the outer ones larger, crowded, flattened, obtuse; the lower ones smaller and more acute. Besides these there are numerous slender, sharp, unequal spines below, and many marginal spinules.

The peractinal row of ossicles is continuous with the inferomarginals, and each bears a cluster of slender spinules, like those of the latter.

The adambulacral plates have an inner, bent, angular or triquetral, subacute spine and about three slightly smaller, slender, roundish, tapered, straight spines in a triangular group on the actinal surface.

A few small actinal plates, near the mouth, bear small, slender spines. A few slender spinuliform pedicellariæ, of diverse sizes, were noticed on the adambulacral plates and on the interradial areas.

Color, mottled gray above, pale yellow below.

This species is not uncommon on the coast, in shallow water, from San Francisco, California, to British Columbia. Departure Bay, in 17 to 25 fathoms, gravel and sand (C. H. Young, 1908, Canadian Geological Survey); Pacific Grove, California (Prof. W. R. Coe); off San Francisco (Prof. W. E. Ritter); Victoria, Vancouver Island (C. F. Newcombe).

Dr. Fisher gives its distribution as from Southern Alaska to San Diego, California, in 10 to 189 fathoms, mostly less than 80 fathoms. He had it from a large number of localities.

LUIDIA LUDWIGI Fisher.

Luidia ludwigi Fisher, op. cit., 1906, p. 122; op. cit., 1911*b*, p. 113, pl. xx, figs. 2, 3; pl. xxi, fig. 2; pl. liv, figs. 2, 2*a*.

Rays five, long and narrow. Radii, 13 mm. and 107 mm.; ratio, 1:8.2. Abactinal area of rays has three or four rows of quadrate paxillæ on each side.

The superomarginal plates have small trivalve and bivalve pedicellariæ.

The inferomarginals have a similar pedicellaria on the upper end, and one to three, mostly two, lateral spines, and three to six enlarged spinelets, on the lower side, with small spinelets over the general surface.

The peractinal plates extend to half the length of the ray; and like those of the interradial areas, each has a rather prominent three-valved pedicellaria.

The adambulacral plates have a curved furrow-spine, three spines on the actinal side, and one or two smaller spines (Fisher).

According to Dr. Fisher, this species occurs from Monterey Bay to Santa Barbara Islands and San Pedro, California, in 15 to 50 fathoms, mostly on bottoms of mud or sand.

LUIDIA ASTHENOSOMA Fisher.

Luidia asthenosoma Fisher, op. cit., 1906, p. 124; 1911*b*, p. 116, pl. xx, fig. 1; pl. xxi, fig. 1; pl. liv, fig. 1.

Rays five, very long, slender, flattened, fragile, with a small disk. Radii, 9 mm. and 86 mm.; ratio, 1:9.5; width of ray at base, 10 mm. to 11 mm.

Inferomarginal plates narrow, forming the margins of the ray, but not extending much on the dorsal surface, each with a transverse row of three large, sharp, acicular spines, and covered with very slender spinules; fascioles deep and wide.

The adambulacral plates have a transverse row of three prominent spines, the inner one being a saber-shaped furrow-spine. The interactinal or peractinal plates have a bivalved, short, blunt, papilliform pedicellaria.

The dorsal paxillæ are stellate; some have two-valved, or sometimes three-valved, pedicellariæ. The superomarginal plates are about twice the size of the adjacent paxillæ. The oral plates have bivalved pedicellariæ (Fisher).

Dr. Fisher records this species from thirty-four localities, in 11 to 339 fathoms, between Monterey Bay and Los Coronados Islands, Lower California.

SPECIES WRONGLY ATTRIBUTED TO THIS FAUNA.

Asterias rubens Linn.—Ives (1890) recorded this from San Luis Obispo. Murdoch recorded it from Point Barrow, Arctic Ocean. The latter proves to be *Allasterias rathbuni* Verrill.

Asterias lurida Phil.—Ives (1889) recorded this from San Diego, California. It is a Chilean species and not likely to be found in Californian waters. The species mistaken for it is uncertain.

Linckia guildingii Gray.—This species is known only from the West Indies and Bermuda. It was recorded with doubt by Ives (1889) from San Diego. Probably his small specimen was the young of *L. columbiæ.*

For southern (Panamic) species recorded from San Diego or further north, see below, p. 346. Perhaps some are errors as to locality due to misplaced labels.

GEOGRAPHICAL DISTRIBUTION.

The following account of the geograhpical distribution of the shallow-water species included in this paper is intended merely to give the general facts, so far as now known to me. No doubt the elaboration of the extensive collections of Forcipulata made by the steamer *Albatross,* from deeper waters, will very materially change the range of many species now known only from the shores and very shallow waters.

For my present purpose, the entire region may be divided into four great faunal districts:

I. *The Beringian or North Alaskan.*—This includes the Arctic Ocean coast of Alaska and all the coasts and islands of Bering Sea, south to the Aleutian Islands and Alaskan Peninsula.

II. *The Columbia-Alaskan.*—This includes the coasts and islands of Alaska, south of the Aleutian Islands, and the entire coast of British Columbia, with Vancouver Island; Puget Sound, and the northwestern coast of Washington; the Gulf of Georgia; and the Straits of Fuca.

III. *The Californian.*—This includes the middle and southern parts of the coast of Washington; all of the Oregon coast; and the coast of California to Point Conception, or the north end of the Santa Barbara Channel.

IV. *The South Californian.*—This includes the coast of southern California, from the Santa Barbara Channel, Santa Rosa Island, and Santa Cruz Island to the middle part of the Lower Californian coast.

This fauna was not originally considered as pertaining to this report, but some of its species were introduced for special reasons. The list, however, is not thought to be by any means complete.

I. THE BERINGIAN FAUNA.

The following species have occurred in less than 60 fathoms. Those with an asterisk prefixed occur also in the North Atlantic, and are believed to be circumpolar.

Those with a dagger prefixed belong more properly to the Columbia-Alaskan fauna, and have their northern limits in the southern part of Bering Sea.

**Asterias acervata* St.
Arctic Ocean; Bering Sea; Bering Strait.

Asterias multiclava Ver.
Arctic Ocean; Bering Sea; Bering I.; Siberia.

A. polythela Ver.
Arctic Ocean.

Leptasterias obtecta Ver.
Bering Sea, 17 fath.

L. arctica (Murdoch).
Arctic Ocean; Point Barrow.

†*L. epichlora alaskensis* Ver.
Aleutian Islands southward to Vancouver I.

**Ctenasterias cribraria* (St.) Ver.
Arctic coast of Alaska.

**Stephanasterias albula* (St.) Ver.
Bering Sea; Arctic Ocean.

Allasterias rathbuni Ver.
Unalaska; Bering Sea.

A. rathbuni nortonensis Ver.
Norton Sd.

Allasterias anomala Ver.
Off St. Michael's I.

†*Henricia leviuscula* (St.).
Bering I. and Aleutian Is. south to southern California.

†*H. leviuscula*, var. *multispina* F.
Bering I., southward to Puget Sound, 0-238 fathoms.

†*H. leviuscula*, var. *spiculifera* (Clark).
Aleutian Is. to Puget Sound.

**H. sanguinolenta* (Müll.).
Arctic coast south to the Aleutian Is.; Point Barrow; off Washington (Fisher).

*Var. *pectinata* Ver.
Arctic Ocean and Bering Sea; 41-349 fathoms.

Var. *rudis* Ver.
Point Franklin, Arctic Ocean, 13½ fathoms.

H. tumida Ver.
Arctic Ocean to Dutch Harbor, Alaska.

H. tumida borealis Ver.
Bering Str., south to Yakutat and Sitka, Alaska; Siberia.
H. arctica Ver.
Cape Lisburne.
†*H. aspera* F.
Bering Sea to Santa Barbara, Calif.
**Solaster endeca* (L.).
Arctic Ocean; Bering Sea, south to Sitka; Queen Charlotte Sd., 238 fath.
†*S. dawsoni* Ver.
Kuril Is.; Aleutian Is., southward to California.
S. dawsoni arctica Ver.
Point Franklin, Arctic Ocean.
†*S. stimpsoni* Ver.
Bering I. and Commander Is., south to Oregon.
S. paxillatus Sladen.
Bering Sea to Kadiak and to Japan; 56-350 fath.
**Crossaster papposus* (L.).
Cape Franklin, Arctic Ocean; Bering Sea to Oregon; Siberia; common off Alaska, 1-283 fath.
†*Pteraster tesselatus* Ives.
Bering I. to Puget Sd.
**P. militaris* Müll.
Bering Str. to Aleutian Is.; Str. of Fuca, 100 fath.
**P. pulvillus* Sars.
Off Bering I., in deep water.
P. marsippus F.
Bering Str., 52-351 fath.
**Pteraster obscurus* (Per.).
Bering Str. to Unalaska and Kamchatka.
P. obscurus, var. *octaster* Ver.
Bering Str. to Pribilof Is. and Kamchatka.
Pterasterides aporus (Lud.).
Bering Sea.
**Diplopteraster multipes* (Sars) Ver.
Bering Sea to Aleutian Is., 81-350 fath.; off San Diego, Calif., 628-640 fath.
**Ceramaster granularis* (R.) Ver.
Bering Sea to Aleutian Is.; Str. of Georgia (?).
C. patagonicus (Sla.) F.
Bering Sea to Aleutian Is. and Unalaska; Southern Alaska, 41-134 fath.; Gulf of California (Fisher).
Tosiaster arcticus Ver.
Bering Sea to Aleutian Is. and Kadiak, Alaska, and to Siberia; 0-102 fath.
†*Hippasteria spinosa* Ver.
Bering Sea to southern California.
Luidiaster dawsoni (Ver.).
Bering Sea to British Columbia, 56-159 fath.
**Leptychaster arcticus* (Sars).
Bering Sea to Bering I., and to Yezo, Japan

L. pacificus F.
Bering Sea to Vancouver I. and to Str. of Georgia.
Glyphaster anomalus (Fisher) V.
Bering Sea to southern Alaska and Japan; 32-688 fath.
**Ctenodiscus crispatus* (Retz.) M. & Tr.
Bering Sea to California and Japan; 31-1033 fath.

II. THE COLUMBIA-ALASKAN FAUNA.

This extensive region comprises by far the longest list of species. Those with an asterisk prefixed belong more properly to the Beringian fauna but extend southward, often far into this, in deep water. Those with a dagger (†) prefixed are more southern species that find their northern limits in the southern part of this fauna. Many species are common to this and the next fauna.

Pisaster ochraceus (Br.) Ag.
Aleutian Is. and Yakutat to Monterey Bay.
Var. *nodiferus* Ver.
Sitka; British Columbia to Gulf of Georgia.
P. confertus (St.) Ver.
British Columbia to Puget Sd. and Vancouver I.
P. lütkenii (St.) Ver.
Vancouver I. to Monterey Bay; and as var. *australis*, to San Diego.
P. paucispinus (St.) Ver.
British Columbia and Puget Sd. to California.
P. papulosus Ver.
Departure Bay, British Columbia, and Puget Sound to Gulf of Georgia.
P. brevispinus (St.) Ver.
Washington to Monterey, California.
Asterias victoriana Ver.
Vancouver I.
A. nanimensis Ver.
British Columbia.
A. katherinæ Gray.
Mouth of Columbia River; Gulf of Georgia.
Leptasterias leptalea Ver.
Southern Alaska.
L. macouni Ver.
British Columbia.
L. inequalis Ver.
Orca, Alaska.
L. coei Ver.
Southern Alaska.
L. vancouveri (Per.).
Vancouver I.
L. hexactis (St.).
British Columbia to Monterey, Calif.; San Diego (?).
L. æqualis (St.).
British Columbia; Puget Sd. to Santa Barbara.

Var. *nana* Ver.
Gulf of Georgia to California.
Var. *compacta* Ver.
British Columbia to Monterey, Calif.
L. epichlora (Br.) St.
Dutch Harbor; Aleutian Is. to Vancouver I.
Subspecies *alaskensis* Ver.
Aleutian Is. to Puget Sd.
Var. *carinella* Ver.
Southern Alaska to Dutch Harbor.
Var. *siderea* Ver.
Aleutian Is. and Yakutat to Puget Sd.
Subspecies *miliaris* Ver.
Southern Alaska to Queen Charlotte Islands.
Subspecies *plena* Ver.
Vancouver I.
Var. *regularis* Ver.
Yakutat to Sitka, Alaska.
Var. *subregularis* Ver.
Southern Alaska.
Var. *subnodulosa* Ver.
Wrangel, Alaska.
Subspecies *pugetana* Ver.
Puget Sound.
L. (?) dispar Ver.
Dutch Harbor to southern Alaska.
Stenasterias macropora Ver.
Southern Alaska.
Evasterias troschelii (St.).
Aleutian Is. to Oregon; abundant from Sitka to Puget Sd. and Str. of Georgia.
Var. *rudis* Ver.
Aleutian Is. to Vancouver I.
Var. *densa* Ver.
British Columbia; Vancouver I.
Var. *subnodosa* Ver.
Aleutian Is. to Sitka.
Var. *alveolata* Ver.
British Columbia; Vancouver I.
Var. *parvispina* Ver.
British Columbia; Sitka, Alaska.
Evasterias acanthostoma Ver.
Vancouver I.; British Columbia.
Orthasterias columbiana Ver.
Yakutat, Alaska, to Victoria, Vancouver I.; La Jolla, Calif.
O. biordinata Ver.
Departure Bay, B. C.
O. kœhleri de Lor.
Vancouver I.
O. leptolena Ver.
Departure Bay, B. C.

O. dawsoni Ver.
Queen Charlotte Is., B. C.
O. (Stylasterias) forreri (Lor.) Ver.
Monterey Bay; Alaska (?).
Orthasterias forreri forcipulata Ver.
Departure Bay, B. C.
O. merriami Ver.
Glacier Bay and off Juneau, Alaska; Gulf of Georgia (?).
Distolasterias chelifera Ver.
Vancouver I.; Alaska (?).
Parasterias albertensis Ver.
British Columbia.
Pycnopodia helianthoides (Br.) St.
Aleutian Is. and Yakutat, Alaska, to Monterey Bay.
Echinaster robustus Ver.
Departure Bay, B. C.
Henricia leviuscula (St.).
Bering I. and Aleutian Is. to San Diego, Calif.
Var. *leviuscula* (St.).
Sitka to San Diego, Calif.
Var. *lunula* Ver.
Sitka to Monterey Bay.
Var. *attenuata* Clark.
British Columbia and Vancouver I. to San Francisco.
Var. *inequalis* Ver.
Queen Charlotte Is., Victoria, Sitka.
Subspecies *spiculifera* (Clark).
Puget Sd. to Bering Sea.
Var. *multispina* F.
Bering I. to Vancouver I.
Var. *dyscrita* F.
Sitka to southern California.
Var. *annectens* F.
Puget Sd. to Santa Barbara, Calif.
Var. *spatulifera* Ver.
Sitka to Monterey Bay; Santa Cruz Is. (?)
**H. sanguinolenta* (Müll.).
Arctic Ocean to Washington; 0-344 fath.
**H. tumida borealis* Ver.
Bering Str. to Yakutat and Sitka, Alaska.
H. longispina F.
S. Alaska to Vancouver I.; 41-134 fath.
H. aspera F.
Bering Sea to Santa Barbara, Calif.
**Solaster endeca* (L.).
Arctic Ocean, Bering Sea, south to Sitka; British Columbia, 238 fath.
S. galaxides Ver.
Vancouver I. and Puget Sd.
S. dawsoni Ver.
Aleutian Is. and Kuril Is. to Monterey Bay; 1-229 fath.

S. constellatus Ver.
Puget Sound.
**S. paxillatus* Sladen.
Bering Sea, south to Kadiak; Japan.
**Crossaster papposus* (Linné) Ver.
Arctic Ocean, south to Vancouver I. and Puget Sd.
Patiria miniata (Br.) Ver.
Middle Alaska, south to San Diego; Gulf of California.
Pteraster tesselatus Ives.
Bering I. to Puget Sd.
P. tesselatus hebes Ver.
Departure Bay, B. C.
P. multispinus Clark.
Puget Sd.
P. gracilis (Clark).
Puget Sd.
**P. militaris* (Müll.).
Arctic Ocean and Bering Sea to Aleutian Is.; Str. of Fuca, 100 fath.
**Ceramaster granularis* (Retz.) V.
Bering Sea to Puget Sd.
C. patagonicus (Sladen) F.
Bering Sea; S. E. Alaska; 41-134 fath.
Mediaster æqualis St.
Alaska Peninsula to Lower California, off Los Coronados Is.
Hippasteria spinosa Ver.
St. Georges I., Bering Sea, and Kadiak, south to southern California; 27-221 fath.
Dermasterias imbricata (Gr.).
Southern Alaska to Monterey Bay.
Var. *valvulifera* Ver.
Sitka to British Columbia.
Luidiaster dawsoni (Ver.).
Bering Sea to British Columbia; 56-159 fath.
Ctenodiscus crispatus (R.).
Arctic Alaska to California in deep water.
Luidia foliolata Gr.
Southern Alaska to San Diego.

III. THE CALIFORNIAN FAUNA.

The following list is not thought to be complete. Probably many more of those in the preceding list will be found to extend into this fauna. The two faunæ blend together and overlap, so that no very definite division can be made. This fauna is a blending of the preceding and following, with few peculiar species. The special distribution of many of the species is given in the preceding list and not repeated here.

Pisaster ochraceus (Br.) Ag.
Var. *nodiferus* Ver.
P. fissispinus (St.) Ver.
Oregon.
P. lütkenii (St.) Ver.
P. paucispinus (St.) Ver.
†*P. capitatus* (St.) Ver.
Monterey Bay to San Diego.
P. giganteus (St.) Ver.
Tomales Bay, north of San Francisco.
P. brevispinus (St.) Ver.
Crescent City to Monterey, Calif.
P. (*?*) *grayi* Ver.
Oregon.
Asterias katherinæ Gray.
Mouth of Columbia; Gulf of Georgia.
Leptasterias hexactis (St.) Ver.
Monterey to Vancouver I.
L. æqualis (St.) Ver.
Vancouver I. to Santa Barbara, Calif.
Var. *compacta* Ver.
Vancouver I. to Monterey, Calif.
Var. *nana* Ver.
Gulf of Georgia to Monterey.
Var. *concinna* Ver.
Monterey, Calif.
Evasterias troschelii (St.) Ver.
Oregon and northward.
Orthasterias californica Ver.
Near San Francisco.
O. forreri (Lor.) Ver.
Monterey and Santa Cruz, Calif.; Alaska (?).
**O. columbiana* Ver.
La Jolla, Calif., to Yakutat, Alaska.
†*O. gonolena* Ver.
Gulf of California; Lower California; Santa Barbara; San Diego, etc.
Pycnopodia helianthoides (Br.) St.
Monterey Bay northward to Kadiak, Alaska.
Poraniopsis inflata F.
Oregon to San Diego; 26-159 fath.
Henricia leviuscula (St.).
Var. *lunula* Ver.
Var. *attenuata* (Clark).
Var. *dyscrita* F.
Var. *annectens* F.
Var. *spatulifera* Ver.
Patiria miniata (Br.) Ver.
Yakutat, Alaska, south to Gulf of California.
Mediaster æqualis St.
Alaska, south to Lower California.

Hippasteria spinosa Ver.
Kadiak to Lower California; 27-221 fath.
Odontaster crassus F.
Monterey to San Diego; 49-284 fath.
Dermasterias imbricata (Gr.).
Alaska, south to Monterey.
Astropecten californicus F.
Monterey Bay to Lower California.
†*A. siderealis* Ver.
Southern California.
Bunodaster ritteri Ver.
Californian coast.
**Ctenodiscus crispatus* (Retz.).
Deep water; California, north to Arctic Ocean.
†*Luidia asthenosoma* F.
Monterey to Lower California.
Luidia foliolata Gr.
Alaska to San Diego.
†*L. ludwigi* F.
Monterey to Santa Barbara.

IV. THE SOUTH CALIFORNIAN FAUNA.

So far as known, this fauna has few species peculiar to it. The species are largely members of the more northern faunæ that extend far south (indicated by an asterisk), and partly species of the more southern fauna of Lower California and the Gulf of California that range northward beyond the normal limits of that fauna (indicated by a dagger). Some of the species, however, appear to be peculiar to this district, so far as known, and others have here their chief development or "center of distribution."

**Pisaster ochraceus* (Br.).
Pisaster capitatus (St.).
? Pisaster brevispinus (St.).
**P. paucispinus* (St.).
Santa Cruz, Calif.
**Pisaster lütkenii* (St.).
Var. *australis* Ver.
Var. *exquiseta* (Lor.).
Santa Cruz, Calif.
†*Marthasterias sertulifera* (Xantus) V.
San Diego (?) to Cape St. Lucas.
**Leptasterias æqualis* (St.).
Var. *nana* Ver.
†*Orthasterias gonolena* Ver.
Santa Barbara to Gulf of California.
O. forreri (Lor.) Ver.
Santa Cruz to Monterey.

†*Echinaster tenuispinus* Ver.
San Diego to Panama.
Poraniopsis inflata F.
San Diego to Oregon.
**Henricia leviuscula* (St.).
San Diego north to Alaska.
*Var. *annectens* F.
Santa Barbara to Puget Sd.
**Var. spatulifera* Ver.
Santa Cruz I., northward.
**H. aspera* F.
Santa Barbara to Bering Sea.
**Patiria miniata* (Br.) Ver.
San Diego and Gulf of California, north to Yakutat, Alaska.
**Mediaster æqualis* St.
Los Coronados Is., Lower California, and off San Diego, etc., north to Alaska Peninsula.
Odontaster crassus F.
San Diego to Monterey Bay; 43-284 fath.
**Hippasteria spinosa* Ver.
Off Santa Catalina Is., Calif., in 80 fath., north to Bering Sea, in 121 fath.
†*Linckia columbiæ* (Gray).
Santa Catalina Is. and San Diego, to Colombia, S. A., and Galapagos Is.
Astropecten siderealis Ver.
San Diego to San Pedro.
A. californicus F.
Lower California to Monterey Bay; San Pedro, etc.; 10-244 fath.
A. ornatissimus F.
Catalina I., San Pedro, etc., Cerros Is. to Lower California; 47-207 fath.
Luidia foliolata (Gr.).
San Diego to southern Alaska, Kassam Bay; 10-189 fath.
L. ludwigi F.
Santa Barbara and San Pedro, Calif., to Monterey; 15-50 fath.
L. asthenosoma F.
Lower California to Monterey; 11-339 fath.

The following species have been erroneously attributed to this fauna:

Asterias lurida (Phil.) = *Cosmasterias lurida*. See below, p. 358.
Recorded by Ives. A Chilean species.
Asterias rubens L.
Recorded by Ives. European; not known from the Pacific Ocean.
Phataria biserialis Gray.
Panamic fauna.
Linckia guildingii Gray.
Recorded by Ives. West Indian.
Astropecten ærstedii Ltk.
San Diego (Ives), 1890. Panamic fauna.

Astropecten erinaceus Gray.
San Diego (Ives), 1890. Panamic fauna.
Luidia brevispina Lütk.
San Diego (Ives), 1890. Panamic fauna.

V. SOME COMPARISONS WITH OTHER FAUNÆ.

The following remarks and lists are intended to give only a general view of the relations of the Northwest Coast faunæ with those of other regions.

As remarked in the Introduction and shown in the preceding lists, a considerable percentage of the starfishes of the Beringian fauna are circumpolar.

The total number of species and subspecies listed in the Beringian fauna is forty-four. Of these fifteen, or thirty-three per cent, are known to be circumpolar. Eight species, or about eighteen per cent, appear to belong more properly to the Columbia-Alaskan fauna, while many of the remaining species extend southward into the latter. Six of the remainder reach Siberia, and four species reach Japan.

About sixteen species are either peculiar to the fauna or have there their principal development, so far as known. Of these, several are so closely allied to North Atlantic and Arctic species that they must be considered as of arctic or subarctic origin. Such are *Asterias multiclava; A. polythela; Leptasterias arctica; Henricia sanguinolenta* var. *rudis; H. tumida borealis; H. tumida; H. arctica; Solaster dawsoni arctica; Pteraster marsippus; Pteraster obscurus octaster; Pterasterides aporus; Leptychaster pacificus.*

It is not improbable that most of these, as well as various species now circumpolar in range, may have originated in Bering Sea or adjacent waters.

A few species are identical with, or more closely allied to, northern Japanese or Asiatic species than to those of any other fauna. These are *Allasterias rathbuni,* and subspecies *nortonensis; A. anomala; Solaster paxillatus, Patiria miniata,* and *Glyphaster anomalus.* Such species may have had their origin on the Asiatic coast, for the oceanic currents are mainly from that direction.

When compared with the Antarctic species, we find very little affinity, except in the cases of a few very widely distributed deep-water genera and species, such as *Ceramaster patagonicus, Ctenodiscus crispatus.* These are of doubtful origin, having related species in many regions. See below.

VI. RELATIONS OF THE COLUMBIA-ALASKAN AND CALIFORNIAN FAUNÆ.

The former includes a total of eighty-five species and named varieties; the latter includes forty altogether. For my present purpose these may best be considered collectively, as they have many species in common. The two lists include ninety-nine species, subspecies, and varieties. Of these only sixteen species and varieties are not known to occur in the Columbia-Alaskan fauna, while twenty-four are common to both.

Of the ninety-nine forms, only about eight are of Arctic origin (indicated by an asterisk in the list), leaving nine-one that may be considered as characteristic of the region. Of this number a few are more or less related to Arctic species generically, or have there their nearest allies.

Among these are *Asterias katherinæ; A. victoriana; Leptasterias leptalea; Solaster galaxides; Hippasteria spinosa.*

A few have their nearest known allies on the Atlantic coast of the United States. Among these are *Orthasterias columbiana,* allied to *O. tanneri* of the Atlantic; *Mediaster æqualis,* allied to *M. bairdii.*

A considerable number belong to genera widely distributed in all the warmer or temperate seas. Among these are the various forms of *Henricia leviuscula; H. longispina; H. aspera; Solaster stimpsoni; S. dawsoni; S. constellatus; Pteraster tesselatus; P. multispinus; P. gracilis;* one species of *Astropecten,* and three of *Luidia.*

The species of *Astropecten* and *Luidia* are probably of tropical origin and their nearest allies apparently still exist in the Panamic fauna.

Many species and several genera of this region do not appear to have any very closely allied species in other seas. Among these are the following: The genus *Pisaster,* with its eleven species and subspecies; *Leptasterias epichlora,* with its ten subspecies and named varieties, none of which seem closely related to Atlantic species; *L. coei; L. hexactis; L. æqualis,* with three varieties; *Evasterias troschelii,* with five varieties; *E. acanthostoma;* eight species of *Orthasterias; Parasterias albertensis; Stenasterias macropora; Pycnopodia helianthoides; Dermasterias imbricata; Bunodaster ritteri.*

The last five are the only known representatives of their genera.

A few species seem to be allied to some of those of the coasts of Peru and Chile, without any allies in the intervening tropical waters. Thus, *Patiria miniata* is not distantly related to *P. chilensis,* with no species of the same genus known between Lower California and

Peru, nor on the Atlantic coasts of America. Yet a much more closely allied species, *P. pectinifera* (Müller and Troschel), is found on the coasts of Japan, extending north at least as far as Vladivostok. Thus, the North American species is most likely a derivative of the Japanese stock. The restricted genus, itself, is widely distributed in the Indian and Pacific oceans, from Cape Good Hope to Australia and Japan, but the Japanese species referred to is decidedly nearer to *P. miniata* than any of the others.[1] All the species of the genus are littoral and shallow-water forms. This renders their wide distribution more remarkable. *Poraniopsis inflata* Fisher is allied to *P. echinaster* Perrier, of Patagonia, etc. *Odontaster crassus* seems to be related to the several forms of the same genus found off Patagonia and Cape Horn, but perhaps no more so than to the three species found off the Atlantic coast of the United States, especially *O. robustus* Verrill and *O. hispidus* Verrill. *Ceramaster patagonicus* is thought by Professor Fisher to have a continuous range, in the deep sea, from Patagonia to Alaska and Japan. The same, he thinks, may be true of *Ctenodiscus crispatus*. I have not personally studied Antarctic specimens of these species. *Luidiaster dawsoni* belongs to a deep-sea genus, widely distributed.

The preceding brief analysis of the faunal lists indicates pretty clearly that much the larger part of the starfishes inhabiting shallow waters of the North Pacific coast, from middle California to Southern Alaska, originated on that coast and have received, at most, only a few additions from the Arctic Ocean and from the Panamic and South American faunæ, in modern (geologic) times.

About one-half (forty-nine) of the total number of species and varieties in the lists belong to the family Asteriidæ.

VII. RELATIONS OF THE SOUTH CALIFORNIAN FAUNA.

The list above includes twenty-nine species and varieties. Of these, twenty-two species occur farther north. Of the remaining six species, three are known to occur in the Panamic fauna, and probably find here their northern limits, viz., *Marthasterias sertulifera; Echinaster tenuispinus; Linckia columbiæ*. These belong to genera widely distributed in tropical seas. The remaining three, at present, seem to belong particularly to this fauna, viz., *Astropecten siderealis; A. ornatissimus; Orthasterias gonolena*.

[1] Professor Fisher, op. cit. 1911*b*, p. 258, has given a very useful table of their differences.

The two species of *Astropecten* are closely allied to Panamic species. The *Orthasterias* is allied to *O. californica* and others from farther north, but it ranges to the Gulf of California.

This faunal district, as now known, does not show any special peculiarities of its own. It is a meeting-ground, so to speak, between the Panamic and the Californian faunæ. Yet the list of species given above is doubtless very incomplete.

It is notable that, while twelve species and varieties of Asteriinæ reach this fauna, only two extend southward to Cape St. Lucas. From thence southward, on the whole extent of the coast to Ecuador, no member of this subfamily is known to occur in shallow water.

From off Mexico, the Galapagos Islands, and Panama, in moderately deep water, Ludwig has described seven species, which he refers to *Stolasterias, Sporasterias,* and *Hydrasterias.* One of these appears to belong to *Coscinasterias,* viz., *C. alexandri* (Ludwig, as *Stolasterias,* p. 221, pl. XXXII, figs. 190-193). It is from the Gulf of Panama, in 95 meters to 384 meters.

Another, which appears to belong to *Stylasterias,* viz., *S. robusta* (Ludwig, as *Stolasterias,* p. 228), is from off the Galapagos, in 704 meters.

The three species referred to *Sporasterias* do not seem to belong to that genus as herein restricted.

S. mariana is from off Las Tres Marias Islands, in 1244 meters; *S. cocosana* is from 245 meters, off Cocos Island; *S. galapagensis* is from off Chatham Island, in 704 fathoms.

The dorsal plates and connective ossicles are broad, imbricated, and have a regularly stichasterial arrangement in the last two species, which are otherwise very distinct.

S. mariana has five rows of dorsal plates and no visible interactinals. It may belong to *Distolasterias.*

Hydrasterias diomedeæ is from 155 meters and 121 meters, off Panama and Cocos Island.

None of these species are nearly allied to any of the shallow water species of California.

The subfamily Asteriinæ is again abundantly represented by shallow-water species on both coasts of southern South America from Chile and northern Patagonia to Cape Horn and the Antarctic Islands. Yet nearly all the species of these regions belong to general not found in the North Pacific and North Atlantic.

VIII. PATAGONIAN, FUEGIAN, AND ANTARCTIC SHALLOW-WATER STARFISHES CONTRASTED WITH THOSE OF THE NORTH PACIFIC COAST.[1]

As already remarked, the Antarctic starfishes are abundant and diversified, especially those of the subfamily Asteriinæ. Most of the latter, found in shallow water, belong to genera peculiar to the southern hemisphere.

One notable peculiarity is found in the large proportion of species that carry and incubate their eggs and young, being brooders, or *pædophoric species*. This peculiarity extends, also, to many of the Antarctic Echinoidea, Ophiuroidea, and Holothurioidea.

The genera of starfishes of the family Asteriidæ, having this habit, differ, also, in anatomical details and in the position of the genital pores from those that produce minute eggs that develop into free-swimming larvæ, as is commonly the case with northern genera.

Most of the *pædophoric* Asteriidæ carry their young in clusters under and around the mouth, as in *Leptasterias* of the north, but *Stichaster nutrix* Studer is described as carrying them in pouch-like diverticula of the stomach, at least in part.

This *pædophoric* habit is not confined to shallow-water and littoral species, for it has been observed in some species from considerable depths, such as *Anasterias belgicæ* Ludwig, and *A. chirophora* Ludwig, taken in 450 to 560 meters, in the Antarctic Ocean (see below). In these species the young are attached together in large groups, like clusters of grapes, by means of their adoral peduncles and a central stalk.

Although many of the Antarctic species agree with *Leptasterias* of the north, in this habit of carrying their young, and some of them, also, in general appearance, they do not appear to be nearly allied.[2] Most of them are regularly monacanthid, while *Leptasterias* is never truly monacanthid. Some are diplacanthid, as in the case of *Podasterias steineni* and *P. lütkenii* (see below, p. 361).

In the case of *Leptychaster kerguelenensis* Smith, the eggs and young are carried on the back, under the protection of the projecting spinules of the paxillæ, which is more analogous to the method in Pterasteridæ, in which the supraspinal membrane gives additional protection, and for a longer period of development.

[1] In the following review I have omitted some imperfectly described forms and all the abyssal species.

[2] It may be safely assumed, I believe, that all species that carry their eggs and young around the mouth, also have their genital pores on the ventral side, and therefore cannot be congeneric with those that have them dorsal, as in typical *Asterias*.

Another striking peculiarity of the Asteriinæ of this region, and of the Antarctic Ocean generally, is the large percentage of species that have the skeletal plates, and sometimes the spines, covered with a thick and soft, but rather tough, dermis, which is usually canaliculated, and often entirely conceals the plates in alcoholic preparations, or even in dry ones.[1] Even the spines, if small, may be submerged in the dermis, or appear as mere papillæ.

In some cases such starfishes have the skeletal plates, more or less aborted, especially the dorsal ones, but sometimes even the upper marginals, as in *Anasterias, Pædasterias,* and *Adelasterias.*

FORCIPULOSA.

No doubt the most peculiar and remarkable species, pertaining to these southern waters, is the *Labidiaster radiosus* Lütken, belonging to the Brisingidæ.

It has a small disk with from twenty-six to forty-two rays, the number increasing with age, and grows to a large size. Unlike the other forms of Brisingidæ, it lives in shallow water, as well as at a considerable depths. It is found on both coasts of Patagonia and off Cape Horn, etc.

The only other described species is *L. annulatus* Sladen. It occurred off Kerguelen Island and Heard Island, in 75 to 150 fathoms, and in the Arafura Sea (?) in 800 fathoms. It has forty to forty-five long, slender rays. It differs considerably in structure from *L. radiosus,* especially in having the dorsal and superomarginal plates nearly abortive distally, on the rays, beyond the genital regions. This last character, with others, should require a generic separation.

Therefore I propose for it the new generic name, *Labidastrella,* with *L. annulata* as its type.

Aside from *Labidiaster,* the most characteristic species belong to the Asteriidæ and Ganeriidæ. There are several genera of Asteriidæ that do not occur in northern seas, while most of the northern genera are entirely lacking. Thus there are no species of true *Asterias, Pisaster, Orthasterias, Evasterias, Urasterias, Allasterias.* It is doubtful if there is any true *Leptasterias,* though some antarctic

[1] The apparent thickness of the dermis depends much on the mode of preservation, which should be stated in descriptions. It is hardened and contracted by strong alcohol, and still more when dried, especially after being in alcohol. In alcohol of about 70 per cent it is more naturally preserved. In very weak alcohol and in formalin it may swell up and become soft. Some of the difficulties in the identification of such starfishes are thus due to the mode of preservation. In more cases it is due to the negligence of the describer in not cleaning and describing the skeletal plates and pedicellariæ.

species have been described that closely resemble that genus, and may possibly belong to it.

On the other hand, there are found in the Patagonian fauna, and farther south, numerous species and varieties of monacanthid starfishes, most of which are known to carry their eggs and young (*pædophoric*) and to have, in those species dissected, ventral genital pores.

These have been referred to the genera *Anasterias* Perrier, 1875; *Calvasterias* Perrier, 1875; *Sporasterias* Perrier, 1894; *Pædasterias* Verrill, gen. nov.

Another group of *pædophoric* species includes several diplacanthid species, belonging to the genera *Podasterias* Perrier and *Granaster* Perrier. None of these are known in the northern hemisphere.

The genera *Meyenaster* Verrill, May, 1913 (monacanthid), and *Cosmasterias* Sladen, 1889 (diplacanthid), also characteristic of this region, have not yet been observed to carry their young.

The most common and abundant littoral and shallow-water starfishes of both coasts of Terra del Fuego and Magellan Strait belong to a monacanthid generic group with a reticulated dorsal skeleton, for which *Sporasterias* Perrier, 1894, seems to be the earliest tenable name, with *S. rugispina* (Stimpson, 1862, as *Asterias*) for its type. This group, which we may also designate as the *rugispina*—or *antarctica*—group, has commonly been called *Anasterias* Perrier. The latter was originally based solely on *A. minuta* Perrier, a small, doubtless very young starfish, with a thick dermis, rudimentary dorsal skeleton, and few dorsal spines, and thus quite unlike the group that we call *Sporasterias*. (See *Anasterias*, below, p. 354.)

F. Leipoldt (op. cit., 1895, p. 563) proposed to unite nearly all the then known monacanthid starfishes of the Antarctic seas into one comprehensive and exceedingly variable species. This would be a very convenient arrangement, perhaps, if it would only prove true. No doubt, however, many of the nominal species of this group are synonymous; and the species are certainly variable, as are all others that carry and incubate their eggs and young.

Among the forms united by Leipoldt, under the name *Asterias rugispina*, the following belong apparently to *Sporasterias*, having a reticulated dorsal skeleton and many spines, not submerged in a thick dermis: *Sporasterias antarctica* (Lütken, 1856); *S. rugispina* (Stimpson, 1862, as Asterias); *S. varia* (Phil., 1870); *S. rupicola* (Verrill, 1876, as *Asterias*); *S. perrieri* (Smith, 1876, six-rayed, as *Asterias, non A. perrieri* Studer, 1884); *S. cunninghami* (Perrier, 1875, as *Asterias*); *S. spirabilis* (Bell, 1881, as *Asterias*); *S. hyadesi* (Per-

rier, 1886, as *Asterias*). Of these, *S. rugispina* appears to be distinct by reason of its large, wide, obtuse minor pedicellariæ, and few, capitate and sulcate dorsal spines. *S. perrieri* Smith, from Kerguelen Island, is regularly six-rayed; *S. rupicola* Verrill, from the same place, a smaller, five-rayed form, with many spines and few and minute pedicellariæ, is apparently distinct. (See below, p. 356.) All the others may well belong to a single species, for which *S. antarctica* (Lütken) seems to be the correct name.

ANASTERIAS (Perrier) restricted.

In addition to all the above forms, Leipoldt includes in the same composite species the following, which have a rudimentary or partly abortive dorsal skeleton; few small imbedded spinules; and a thick dermis that conceals the plates, and largely the spinules. These constitute, with others, the restricted genus *Anasterias* (*Lysasterias* Fisher): *Anasterias minuta* Perrier, 1875 (type); *A. perrieri* (Studer), 1884 (*non* Smith); *A. verrillii* (Bell, 1881, as *Asterias*). Also *Calvasterias stolidota* Sladen.

Fisher (1908, p. 88) proposed the name *Lysasterias* to replace *Anasterias* Ludwig, with *Asterias perrieri* Studer, of South Georgia, as the type, assuming that *A. minuta* belongs to a distinct genus and is identical with *S. rugispina,* etc. However, the original description by Perrier shows that it has only isolated dorsal plates, covered with a thick dermis; few imbedded dorsal spinules; numerous pedicellariæ, and most of the other characters as in *A. perrieri* Studer and *A. studeri* Perrier. Therefore, it is most likely the young of one of these or of some other closely allied species of the same group, and not the young of *rugispina,* nor of *spirabilis,* as has been thought, for the young of that group, when of similar size, have a reticulated dorsal skeleton, abundance of spines, and the dermis not thick enough to conceal the plates. Hence, I consider *Lysasterias* Fisher a synonym of *Anasterias.*

Since the specific name, *Asterias perrieri* Studer (1884), was preoccupied by *A. perrieri* Smith, 1876, it requires a new name. Therefore, I propose to call it ANASTERIAS LYSASTERIA.

To the genus *Anasterias* (restr.) Ludwig (1905, p. 42) added, besides the two species above named, three new species from deeper water, southwest of Cape Horn. The described species are as follows:

A. minuta Per., 1875.
Patagonian and Fuegian; shallow-water.
A. lysasteria Ver., nom. nov. = *A. perrieri* (Std. *non* Smith).
South Georgia, cast ashore; also Fuegian (t. Perrier).
A. studeri (Per.), 1891.
Falkland Is., 320 meters; carried young.
A. verrillii (Bell, 1881, p. 513, pl. XLVII, fig. 3, as *Asterias*).
Fuegian; Gregory Bay, etc., littoral.
A. lactea Lud. (1903, p. 50).
About S. lat. 71°, in 450 meters.
A. belgicæ Lud. (1903, p. 51).
About S. lat. 70°, in 560 meters; carried young.
A. tenera (Kœhler, 1905).
Wandel I.; carried young.

The attached young of *A. belgicæ* were described by Ludwig, 1903, p. 53, pl. VI, figs. 61-65; pl. VII, figs. 66, 67.

For the following species, placed in *Anasterias* by Ludwig, I propose to establish a new genus:

Genus **Pædasterias** Verrill, nov.

Type *A. chirophora* (Ludwig, op. cit., 1903, p. 43, plates V, VI, VII).

This is monacanthid and incubates its young, and therefore probably has ventral genital pores. Its skeleton is more reduced than in *Anasterias,* the upper marginal plates being absent, except as rudiments distally. It is covered by a thick dermis and bears large, wide, felipedal pedicellariæ.

It is found at from 450 to 560 meters, in the Antarctic Ocean, southwest of Cape Horn, about S. lat. 70° to 71°.

Ludwig has carefully described and figured the attached young.

Genus **Sporasterias** Perrier.

Type, *Asterias rugispina* Stimpson.

Sporasterias PERRIER, 1896, p. 55.
Anasterias (*pars*) PERRIER, 1891 (*non* 1875).
Sporasterias LUDWIG, 1905.

This is a monacanthid genus with a reticulated dorsal skeleton, not replaced by a thick dermis, bearing numerous small, scattered spines, and usually numerous pedicellariæ of both kinds.

Interactinal spines are usually absent; sometimes there is an imperfect row. Inferomarginal spines are usually two to a plate; superomarginal ones usually one to a plate; interactinal papulæ usually solitary, enlarged proximally; jaws and adoral ridge narrow, elongated.

SPORASTERIAS PERRIERI (Smith).

Asterias perrieri SMITH, Ann. and Mag. Nat. Hist., ser. 4, XVII, p. 106, 1876 (*non* Studer, 1884; *non Anasterias perrieri* Ludwig, 1905).

This is a true *Sporasterias,* with well developed skeleton and numerous spines. It is reguarly six-rayed. Smith states that his largest specimen carried hundreds of attached young, all of which were six-rayed. It appears to be clearly distinct from the *rugispina-antarctica* group.

The type was from Kerguelen Island, in 5 to 10 fathoms.

SPORASTERIAS RUPICOLA Verrill.

Asterias rupicola VERRILL, op. cit., 1876, p. 74.

This is a small, short-rayed form. The types, which were from Kerguelen Island shore, have the following characters when dry:

The dorsal skeleton is pretty well developed, openly reticulated, with numerous moderately large papular areas, evenly distributed, larger on the basal part of the rays, mostly with two to four or five papulæ; single ones occur distally. The dorsal plates are not concealed by the dermis; the dorsal spines are evenly distributed, short, clavate, subequal, with no evident larger median row, one to three on the small nodal plates.

The superomarginal spines form a distinct simple row, one to a plate. The plates being stout and imbricated. The inferomarginal plates mostly bear two larger and longer clavate spines. A wide lane between the upper and lower marginal rows, broadening proximally, has a row of large papular areas, with three to five papulæ separated by stout descending apophyses of the superomarginal plates, some of which carry a single small spinule.

A short interactinal row of small plates exists proximally, some of them bearing a single spine. Between these is a row of single papulæ; the proximal ones are often larger than the spines and inflated, as in other allied species.

The adambulacral spines form a single regular row; they are smaller and more slender than the inferomarginals, and are distinctly clavate. The interradial axils are covered with a thicker canaliculated dermis without spines. The jaws are narrow.

Major pedicellariæ are few and small; some along the furrow margins and on the oral spines are thick, ovate or blunt-lanceolate; a few smaller, more acute ones are on dorsal spines. Minor pedicellariæ appear to be lacking in the several types. They are abundant in *S. rugispina* (Stimpson) and most of the other allied forms, and there are other notable differences in the spines and skeleton.

Types 3145 U.S.N.M. Kerguelen Id. Dr. J.S. Kidder
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Genus **Calvasterias** Perrier.

Type, *C. asterinoides* Perrier; Sladen, 1889, p. 589.

Calvasterias Perrier, op. cit., 1875, p. 348.

This is another genus in which the skeleton, and also, largely, the spines, are covered with a thick, soft dermis, entirely concealing the plates.

It is monacanthid. An imperfect spiniferous interactinal row of plates is present; usually there are two rows of inferomarginal spines and a single row of superomarginals. Position of genital pores unknown; nor is it known whether the young are incubated.

The dorsal skeleton in the type consists of wide, lobed or substellate, imbricated plates, overlapping in both directions by their lobes, as in *Stichaster*. Descriptions and figures of other species do not show the character of the plates, and some may not be congeneric, if the plates prove to be abortive or rudimentary.

In the type the dorsal spines are few, short, capitate, nearly concealed by the dermis and an abundance of papulæ of similar size.

The type was supposed to have been from Torres Strait, but Sladen records the species from the Falkland Islands.

CALVASTERIAS (?) STOLIDOTA Sladen.

C. stolidota Sladen, 1889, p. 590, pl. ci, figs. 3, 4; pl. ciii, figs. 11, 12.

This has longer rays than the type, with more evident, scattered dorsal spines, which are short, rough, capitate. The skeleton was not described, and so it may not be a true *Calvasterias*. Leipoldt united it to *Sporasterias rugispina*, with doubt.

This is from both coasts of Patagonia and the Falkland Islands, in 5 to 10 fathoms.

MEYENASTER GELATINOSUS (Meyen, 1834, as *Asterias*).

Asterias rustica Gray, 1840, p. 179; Synopsis, p. 1, 1866.

Asterias gelatinosa Clark, op. cit., 1910, p. 337, pl. vi, fig. 2.

Meyenaster gelatinosus Verrill, Amer. Journ. Science, xxxv, May, 1913, p. 348. See also Introduction, above, p. 54, for generic characters.

This is a large, and a very characteristic species on the west coast of Chile, from Iquique southward. It grows to the diameter of 20 inches or more. It is monacanthid and usually six-rayed, yet five-rayed and seven-rayed specimens are frequently found.

The only other species of the genus, known to me, is supposed to be from the Society Islands (No. 1427, Coll. Mus. Comp. Zoöl.). That

is a large, five-rayed species, similar as to spinulation and thick dermis, but with very unlike pedicellariæ.

Its major pedicellariæ are remarkably slender, numerous, part of them large, narrow-lanceolate and acute. The minor pedicellariæ are minute and very abundant, both on the dermis and on thick sheaths around the sulcated dorsal spines.

This genus somewhat resembles *Marthasterias*.

Genus **Cosmasterias** Sladen, 1889.

Type, *Asterias sulcifera* Perrier, 1869, = *C. lurida* (Phil.).

Diplasterias (*pars*) Perrier, 1891.

This is also a genus apparently peculiar to the Patagonian and Fuegian region, where one species is abundant in shallow water and often at low tide.

It is diplacanthid; jaw-spines and adorals are elongated; the dorsal plates form several longitudinal bands or rows, and in the adult each plate bears a group of short, unequal spines. There is at least one row of interactinal spines; often three or more rows, when adult. Large unguiculate or felipedal pedicellariæ are found, above and below. Neither of the species has been observed to carry the young.

COSMASTERIAS LURIDA (Phil., 1858) Ludwig, 1905.

Cosmasterias sulcifera (Perrier, 1869, as *Asterias*) Sladen, 1889. To this species Leipoldt, 1895, unites the following: *Asteracanthion clavatum* Phil.; *A. fulvum* Phil.; *A. spectabile* Phil.; *A. mite* Phil.; and *Stichaster polygrammus* Sladen, 1887, 245 fathoms.

The species last named seems to me clearly distinct. (See below, p. 360.)

To the synonyms of this species it will probably be necessary to add *Asterias obtusispinosa* Bell, 1881, p. 92, pl. IX, fig. 3; and *A. neglecta* Bell, op. cit., p. 94, pl. IX, fig. 4. Both are Patagonian; the former from Sandy Point, 9 to 10 fathoms. *C. alba* (Bell), loc. cit., p. 92, pl. IX, fig. 2, also from Sandy Point, may not be distinct, though it has somewhat longer spines.

C. sulcifera has been considered the type of *Cosmasterias* Sladen and *Diplasterias* Perrier. (See, also, Introduction, p. 48.)

It is diplacanthid and has several (two or more) rows of interactinal plates; its dorsal plates form unequal longitudinal rows, each plate, in the adults, bearing a transverse group of short, unequal spines, becoming numerous in large specimens. The minor pedicellariæ are abundant around the spines and on the dermis, and there are many large, scattered major pedicellariæ, some of them unguiculate or dentate.

It varies much in appearance, according to age, and has many local or casual varieties. Whether all the forms referred to it by Leipoldt and others really belong together seems to me somewhat uncertain.

I have studied a series of young and old from Eden Harbor, Patagonia, sent by the Museum of Comparative Zoölogy. These show wide variations, especially in the character of the dorsal rows of spines and the number of spines on each plate. The number increases rapidly with age, so that the larger specimens (radius, 175 mm.) have very numerous, crowded, transverse groups of spines and pedicellariæ, the median and some of the others forming thick, wide, longitudinal rows. The madreporic plate is surrounded by a circle of small special spines, increasing in number with the age, from six or seven up to twenty or more.

The major pedicellariæ are large and stout. Some are obtusely lanceolate or ovate, others are blunt and unguiculate, with few teeth. They are abundant on the edge of the grooves, where many have long, slender pedicels, and between the ventral and lateral spines, and on the dorsal papular areas, where they are often stouter than the adjacent spines. Minor pedicellariæ are abundant on the dorsal dermis, crowded, especially over the transverse ossicles and between the spines.

The larger specimens may have six to eight interactinal spines in a transverse row, arising, apparently, from three, to five, rows of plates. Young specimens, with the greater radius 50 mm., have only two rows of interactinal plates, each with one or two spines, and the spines on both marginal rows stand partly singly, partly two to a plate; there are but three dorsal rows, and the spines in these stand partly in pairs, partly singly.

This species occurs on both coasts of Patagonia and Fuegia, from low tide apparently to 348 fathoms.

COSMASTERIAS TOMIDATA (Sladen).

Cosmasterias tomidata SLADEN, 1889, p. 576.

This has more regular rows of small, clustered dorsal spines, and very numerous dermal minor pedicellariæ, larger than usual. The major pedicellariæ are numerous, large and stout, often much larger than the spines; mostly strongly felipedal.

Gulf of Penas, 45 fathoms, Sladen; Porto Lagunas, etc., 50 to 80 meters, Leipoldt; off Argentina, S. lat. 44° 52′, 55 fathoms, coll. Mus. Comp. Zoölogy.

COSMASTERIAS POLYGRAMMUS (Sladen, 1889) Verrill.

Stichaster polygrammus SLADEN, op. cit., 1889, p. 434, pls. C, CIII.

A diplacanthid species, easily distinguished by the conspicuous transverse or banded arrangement of the dorsal and lateral spines and plates. The dorsals and superomarginals form about seven longitudinal rows. The spines are small and numerous, arranged in narrow transverse rows of three to seven on the ossicles. The major pedicellariæ are large; some of them are felipedal. Papular areas are in regular rows. Ventral plates bear four or five spines in the transverse rows. Position of genital pores unknown.

The type was from 245 fathoms, west of Magellan Strait.

Leipoldt considered this a form of *Cosmasterias sulcifera*. The differences are notable.

COSMASTERIAS BRANDTI (Bell) Verrill.

Cosmasterias brandti (BELL, 1881, p. 91, pl. IX, fig. 1, as *Asterias*).

The dorsal and lateral plates are said to be about eleven in each transverse row, and to bear small spines, in transverse series. It may be the same as *C. polygrammus*.

Trinidad Channel, at 30 fathoms.

COSMASTERIAS FERNANDENSIS Meissner.

Cosmasterias fernandensis MEISSNER, 1896, p. 104, pl. VI, fig. 1, as *Asterias*. [*Polyasterias*] *fernandensis* de Loriol, op. cit., 1904, p. 41, pl. III, figs. 4-8 (rays unequal, five or six).

This has been recorded by Loriol from Gulf San Mathias, E. Patagonia. The type was from Juan Fernandez. It appears to be autotomous, though often five-rayed.

GASTRASTER STUDERI de Loriol.

Gastraster studeri DE LORIOL, 1904, p. 34, pl. IV, figs. 3-3*f*.

This has four irregular rows of podia proximally, but only two rows on the distal half of the rays. Its relations are obscure. It may be allied to *Granaster biseriatus* Kœhler.

From Gulf San Mathias.

Genus **Adelasterias** Verrill, nov.

Type, *A. papillosa* (Kœhler, 1905, as *Diplasterias*).

This is diplacanthid and is covered everywhere with a thick dermis, which rises into numerous papilliform processes, both on the

back and on the sides, which enclose rudimentary or nearly abortive spinules. The skeleton is almost entirely abortive; marginal plates are not present, unless as rudiments.

The type is from the Antarctic Ocean.

Genus **Podasterias** Perrier, 1896.

Type, *P. lütkeni* Perrier.

Diplasterias (*pars*) PERRIER, 1891, p. K, 77. Ludwig, Voy. Belgica, 1903.

This genus is here extended to include several pædophoric diplacanthid starfishes having a reticulated dorsal skeleton, not concealed by a thick dermis, and usually two or more rows of interactinal plates and spines. Thus they have a general resemblance to typical *Asterias,* like *A. rubens.* As some of the species are known to carry their young, the genital pores are presumed to be ventral, but I do not know that any species has been dissected with reference to this. Among the species that appear to belong here are the following:

P. lütkeni (Perrier, 1891, p. K, 81, as *Diplasterias*).
Fuegian and Falkland Is., 95 to 220 meters.

Podasterias steineni (Studer, 1885, pl. 1, figs. 4*a, b,* as *Asterias*). *Diplasterias steineni* Perrier, 1891, p. K, 84.
South of Cape Horn, 99 meters (Perrier).

P. loveni (Perrier, 1891, p. K, 80, as *Diplasterias*).
S. lat. 52° 44′ 31″, 320 meters.

P. spinosa (Perrier, 1891, p. K, 82, as *Diplasterias*).
S. lat. 47° 29′, depth not recorded.

P. meridionalis (Perrier, 1875, p. 340, as *Asterias*).
Antarctic Expedition.

Some of the several species, from the same region, described by Bell in 1881, probably also belong here, but the skeletal structure was not described.

The first two species have been found carrying their young.

The name *Diplasterias* Perrier is not adopted for this genus because, as originally defined, its only character was the existence of at least two rows of adambulacral spines. This made it synonymous with typical *Asterias,* which was the evident intention of Perrier, for he restricted *Asterias* to the monacanthid species.

In the second place, his first species was *A. sulcifera,* which he evidently regarded as the type. But Sladen's report was published while his was being put in type. So that in an Appendix, p. K, 160, he admits the priority of *Cosmasterias* for *sulcifera* and abandons both *Diplasterias* and *Podasterias* (MS. name) and refers *lütkeni* (*non* Stimpson) and its congeners to *Asterias.* This will not hold

good, for his *lütkenii* is pædophoric. In a later work (1896, p. 35) he revived *Podasterias,* with *P. lütkeni* Perrier as the type.

Fisher, 1908, p. 89, considered *lütkeni* Perrier a *Pisaster,* and suggested a change of name, owing to the priority of *Pisaster lütkenii* (Stimpson). They are not congeneric, the latter being monacanthid, and therefore no change is needed in the specific name.

Genus **Cryptasterias** Verrill, nov.

Type, *Diplasterias turqueti* Kœhler, 1905, p. 465.

This is diplacanthid and has a reticulated dorsal skeleton entirely concealed by a thick dermis. The dorsal surface bears soft dermal papillæ, some of which bear a few pedicellariæ; others, scattered, contain rudimentary spinules. There is a simple row of superomarginal spines and a double row of inferomarginals; apparently there are no interactinal plates. It is supposed to incubate its young. Antarctic.

STICHASTER STRIATUS Müller and Troschel, 1840.

Asterias aurantiaca Meyen, Reise um die Erde, 1, p. 292, 1834 (*non* Linné).
Stichaster striatus Müller and Troschel, op. cit., 1840, p. 321 (*non Asterias striatus* Lam.).
Stichaster aurantiacus Verrill, 1867, p. 293. Clark, 1910, p. 337, pl. viii, fig. 1.
Tonia atlantica Gray, op. cit., 1840, p. 180; Synopsis, 1866, p. 2.

This is, perhaps, the most abundant littoral starfish found on the entire coast of Chile, south to Talcahuano, extending northward to Callao, Peru (Yale Museum, F. H. Bradley). Common at Valparaiso, on rocks. It grows to large size, up to 12 inches in diameter or more.

It is the true type of the genus *Stichaster,* being the only species named when that genus was proposed in 1840. Perrier (1894, p. 131; 1896, p. 27) was in error in making *Asterias rosea* the type. (See also Introduction, p. 40.)

It is not generically related to any North Pacific species. It is perhaps the only known species that can be properly referred to the genus *Stichaster.* Nearly all those referred to it by Sladen and others have already been separated generically,[1] except, perhaps, *S. polyplax* of the Australian region. This should clearly be generically distinct. I would propose for it the name *Allostichaster.*

[1] Perrier, 1894, proposed the genus *Granaster* for *Stichaster nutrix* Std.; but *G. biseriatus* Kœhler (antarctic) seems to be a distinct genus, as it has only two rows of podia. It may be called HEMIASTERIAS with *biseriatus* as the type.

Genus **Allostichaster** Verrill, nov.

Type, *A. polyplax* Müller and Troschel.

It is diplacanthid and multiple-rayed, with one to five madreporic plates, and is probably autotomous. The two rows of marginal plates are stout and imbricated; dorsal plates and spines form five somewhat irregular longitudinal rows, several short, obtuse spines on each plate. Minor pedicellariæ are dermal, usually not circumspinal.

SPINULOSA.

The Echinasteridæ are well represented by *Henricia,* several species; *Poraniopsis,* one species; on the coast of Chile, by *Echinaster;* at the Falkland Islands, by *Cribraster sladeni* Perrier.

Henricia seems to have several species and subspecies, and these vary much as do the northern species.

H. obesa (Sladen, 1889) was described as from a depth of from 12 to 245 fathoms. Magellan Strait; Falkland Islands.

H. pagenstecheri (Studer) was originally from South Georgia. Shallow water (?).

H. hyadesi (Perrier 1891, as *Cribrella*), Clark, 1910, p. 337, pl. II, fig. 5. This was recorded by Perrier from Fuegia, etc., and by Clark from Chile (ex. Meissner); 35 to 200 meters (Perrier).

H. studeri (Perrier, 1891), from Magellan Straits, in 9 to 183 meters.

Ludwig, 1905, seems to consider all these as variations of *H. pagenstacheri.* To me most of them seem as distinct, if correctly described and figured, as some of them are from the corresponding Arctic forms. These species of *Henricia* are all pretty closely related to the northern and Arctic species, contrary to those of the Asteriidæ.

Cribraster is known only from the Falkland Islands; depth not known, probably littoral. *C. sladeni* Perrier, 1901 (p. K, 104, pl. XI, figs. *2a, 2b,* and Appendix, p. K, 161).

Echinaster antonioënsis Lor., 1904, and *E. lepidus* Lor., 1904, have been described from the Gulf of San Mathias. *E. lepidus* is said to lack interradial papular pores, and in that case it belongs to *Rhopia* Gray, near *R. sepositus,* of the Mediterranean. The former species is related to *E. brasiliensis.*

Poraniopsis echinaster Perrier, 1891 (p. K, 106, pl. X, figs. *2, 2a,* 95 meters). This is nearly related to *P. inflata* Fisher, from the North Pacific.

Poraniopsis mira (=*Lahillia mira* de Loriol, op. cit., 1904, p. 33, pl. III, figs. 1-1*h*).

This is a large species with short, stout rays, from the Gulf San Mathias, E. Patagonia.

Perknaster densus Sladen. Off Kerguelen Island; 127 fathoms.

P. fuscus Sladen. Off Heard Island and Kerguelen Island; 25 to 75 fathoms.

The family Acanthasteridæ, pertaining almost entirely to tropical seas, and always rather rare, is said to be represented by a species in the Magellan Straits, but the only record seems to be an ancient one and may not be reliable. It has not been found there by any recent expedition.

Acanthaster solaris (Schr.) Duj. et Hupé (*pars*) was described by Gray, 1866 (as *Echinaster solaris*), from this region, but apparently without any modern record. According to him, it has twenty-one rays and ten madreporic plates. Duj. and Hupé united all the known species under this name.

A. ellisii (Gray) occurs in the Panamic fauna. It usually has from eleven to thirteen rays.

The oldest known species, *A. planci* (Linné, Syst. Nat., ed. X, Appendix, p. 823, as *Asterias planci*), occurs apparently throughout most of the Indo-Pacific Oceans, in the tropical zone. The type was described by Linné as having fifteen rays. It came from Goa, Portuguese India, and the figure of Columna (Phytobasanos, pl. XXXIII, fig. A) was referred to as its basis. The figure is characteristic and the name should be adopted. It is the same as *A. echinus* (Ellis and Sol.)=*A. echinites* of Lam. and of many recent writers.

The number of rays and madreporic plates is variable. Usually there are from fifteen to twenty very spinose rays.

The family Asterinidæ is unusually well represented. On the coast of Peru and southward *Patiria chilensis* (Lütken) and *P. gayi* (Perrier) are recorded. They are closely related and probably not dinstinct species; also, *Patiriella calcarata* (Perrier) and *P. pusilla* (Perrier). *Desmopatiria flexilis* Verrill probably occurs on the same coast, but its origin is not positively known.

Farther south, on the coasts of Chile and Magellan Strait, and around Tierra del Fuego to Cape Horn, the very common, small, littoral and shallow-water species is *Patiriella fimbriata* (Perrier) or *P. bispinosa* (Perrier), if the latter, a supposed variety, proves to be distinct.

P. fimbriata, as originally described, was labelled as from Bourbon Island, but Perrier himself expressed doubt as to whether the locality labels were correct, owing to the close agreement with specimens from Chile.

The type had mostly a single spine on the ventral plates, while the Patagonian form usually has two spines on many of the plates. There are, also, some differences in the dorsal spinulation, so that they may prove to be distinct; yet I am not aware that it has been found in tropical seas by later collectors, and the ancient Bourbon Island label may have been wrong. I have examined numerous specimens from Magellan Strait, and found but little variation, but have seen no authentic tropical specimens. It has a thicker dermis than usual, and is not a typical *Patiriella*.

P. calcarata and *P. pusilla* are, however, more nearly allied to several African and Australian species than to any in the northern hemisphere.

Asterinides perrieri=Asterina perrieri de Loriol, 1904, a small species from E. Patagonia, Gulf of San Mathias, appears to belong to the genus *Asterinides,* but may be closely related to *P. fimbriata* or *bispinosa.*

Enoplopatiria marginata, which has been recorded from near the eastern end of Magellan Strait, is a common Brazilian species, extending northward to the West Indies, and recorded also from the west coast of Africa. A closely related new species, *E. siderea,* in our collection, is labeled as from Panama (donor, Captain Dow, of the Panama and California steamship line).

E. siderea Verrill is a rather large species, radii, 24 mm. and 48 mm., with stout, short, broad rays and well defined papular areas, with numerous forked dorsal pedicellariæ; ventral plates with a comb of three elongated spines; four webbed furrow spines.

It differs from *E. marginata* in having the spinules of the interradial dorsal plates longer, widely divergent, stellate and paxilliform, and in other characteristics; but it is evidently closely related, so much so that I formerly suspected the correctness of the label, thinking that it might have come from Colon, on the Atlantic side, and might be only a large variety of *E. marginata.* See plate CIX, figure 4.

The family Ganeriidæ is very characteristic of the Patagonian-Fuegian fauna. Indeed, nearly all the known genera and species are from that region and adjacent districts.

Of the genus *Ganeria* Gray, 1847, Perrier, 1891, recognized four species; viz.: *G. falklandica* Gray, 1847, Falkland Islands; east of Magellan Strait, 55 fathoms, Sladen; *G. robusta* Perrier, 1891, 28 meters; *G. hahni* Perrier, 1891, 138 meters; *G. papillosa* Perrier, 1891, depth not given.

The genus *Lebrunaster* Perrier, 1891, p. K, 116, type *L. paxillosus* Perrier, from Patagonia, depth unknown, is known only from this fauna.

Numerous nominal species of *Cycethra* have been described from Magellan Strait and the coasts of Patagonia and Terra del Fuego, where the genus is common and variable.

Ludwig, 1905, reduces them mostly to varieties of *C. verrucosa* (Phil.). This species includes *C. nitida* Sladen, Meissner + *C. electilis* Sladen, Leipoldt + *C. simplex* Bell, Meissner + *C. pinguis* Sladen + *C. ganeriodes* Perrier + *C. elongata* Perrier + *C. media* Perrier + *C. asterina* Perrier + *C. subelectillis* Perrier + *C. calva* Perrier + *C. regularis* Perrier + *C. asteriscus* Perrier. The last eight forms were regarded by Perrier himself as mere varieties of *C. simplex*, as well as some of the others.

They are common in Magellan Strait and southward to Cape Horn, from low tide to 40 fathoms. *Cycethra lahillei* de Loriol, 1904, p. 25, pl. 11, fig. 2, from Gulf of San Mathias, appears to be a distinct species, with short rays, imperfectly developed marginal plates, and slender paxilliform spinules.

One of the generic types, common to this region and the North Pacific, is *Peribolaster*, of the family Korethrasteridæ, of which only two species are known. *P. foliculata* Sladen occurred in 45 fathoms, west of Patagonia. *P. biserialis* Fisher, 1911, ranges from California to Bering Sea, in from 57 to 313 fathoms.

The family Solasteridæ is represented in moderate depths by *Solaster australis* (Perrier) and *Lophaster stellans* Sladen, both of which have occurred in from 30 to 40 fathoms. In greater depths several additional species of those genera occur. (See list of deeper-water species below, p. 368.)

These are genera widely distributed in all seas, especially in rather deep water, coming into shallow water only in the colder regions. Some of the Antarctic species are closely allied to those of the North Pacific and Arctic Ocean, like those of other families from deep water.

The Pterasteridæ are also well represented by several species of *Pteraster* and *Diplopteraster* in waters of somewhat greater depths. These are also allied to the corresponding species of the North Atlantic and North Pacific. (See list of deeper-water species below, p. 368.)

The genus *Retaster*, which is represented by two species, does not occur in northern waters, but is found in the Indo-Pacific region. from Cape Good Hope to Australia. The Patagonian species are as follows:

R. gibber Sladen, 1889; Ludwig, 1905, pl. v, figs. 6, 7. This occurred in from 14 to 245 fathoms, in Magellan Strait.

R. verrucosus Sladen. This occurred in 55 fathoms, in Magellan Strait.

PHANEROZONA.

The family Odontasteridæ is better represented in the Fuegian fauna than in most regions, some species occurring commonly even at low tide and in shallow water. Several nominal species have been described, some of which Ludwig (1905) and others reduce to synonyms. Ludwig recognizes three shallow-water species; viz.:

1. *O. grayi* (Bell, *non* Perrier) = *Gnathaster grayi* Sladen = *O. pedicellaris* (Perrier).

2. *O. penicillatus* (Phil.) + *O. pilulatus* (Sladen, as *Gnathaster*) + *O. meridionalis* (Smith). Leipoldt, 1895.

3. *Asterodon singularis* (Müller and Troschel) Leipoldt, 1895, pl. xxxi, figs. 7*a-c*, as *Odontaster* = *A. granulosus* Perrier, 1891, pl. xi, figs. 4*a, b*.

A. belli (Studer) Perrier is probably not distinct from *A. singularis*.

The first species is from a depth of 10 to 97 meters. The second species ranges from 5 to 150 fathoms. Several other antarctic species have been described from deeper water. (See Sladen; also Kœhler, 1905.)

Luidia magellancia Leipoldt, 1895, p. 610, pl. xxxii, figs. 11*a-c*. This is remarkable as inhabiting cold waters, for all the other numerous species inhabit tropical or temperate seas. The type had the radii 208 m. and 35 m; ratio, 1:6. Its nearest related species are *L. bellonæ* Lütken, which ranges from Chile to Mexico, and *L. phragma* Clark (1910, p. 329, pl. ii, fig. 1), which was supposed to be from Peru. This may, therefore, be considered as one of the few that were probably of Panamic origin.

IX. LIST OF PATAGONIAN AND FUEGIAN[1] STARFISHES FOUND IN FROM 50 TO 500 FATHOMS, MOSTLY RELATED TO NORTHERN OR ARCTIC SPECIES.

In the somewhat deep, cold waters on the " continental slopes " (50 to 500 fathoms), a considerable number of genera and species have been found that are closely related to those of the North Pacific and North Atlantic and the Arctic Ocean. Many of these have been recorded by Sladen, 1889; Perrier, 1891; Leipoldt, 1895; Ludwig, 1905; Kœhler, 1905, and others. Among them are the following:

[1] Some species from Kerguelen Island, etc., are here included, but some are common to the two regions.

Coscinasterias candicans (Lud., 1905, as *Stolasterias*).
S. lat. 70° to 71°; 450 to 560 meters.
Pedicellaster antarcticus Lud., 1905.
430 to 450 meters.
P. scaber (Smith) Perrier.
Kerguelen I., etc.
Henricia simplex (Sladen, 1889, as *Cribrella*).
Antarctic; 50 to 310 fathoms.
H. præstans (Sladen, as *Cribrella*).
210 fathoms.
H. hyadesi (Perrier, 1891).
35 to 200 fathoms.
Echinaster smithii Ludwig.
450 meters.
Solaster octoradiatus Ludwig.
450 to 500 meters; S. lat. 70° to 71°.
Solaster subarcuatus Sladen.
150 fathoms.
Solaster regularis Sladen.
175 fathoms.
S. australis (Perrier).
65 to 198 meters.
Lophaster stellans Sladen.
40 to 1325 fathoms. Includes *L. pentactis* Per., 200 meters.
Pteraster stellifer Sladen.
245 fathoms.
P. rugatus Sladen.
150 fathoms.
P. ingouffi Per.
Fuegian; 270 meters.
P. lebruni Per.
Fuegian; 80 meters; 450 meters, Ludwig; S. lat. 71° 24′.
Diplopteraster verrucosus (Sladen, as *Retaster*).
East of Magellan Strait; 55 fathoms.
D. peregrinator (Sladen, as *Retaster*).
Kerguelen I.; 127 fathoms.
Hymenaster perspicuus Lud.
400 to 450 meters.
Porania antarctica Smith.
Kerguelen I.; South Georgia; Magellan Strait; Antarctic Ocean, S. lat. 71° 18′, 450 meters; Fuegian, 10 to 1,600 fathoms. Includes *P. magelhænica* Studer and *P. patagonica* Perrier.
P. glaber Sladen.
30 to 127 fathoms.
Odontaster cremens Ludwig.
450 meters.
Mimaster cognatus Sladen.
245 to 1325 fathoms; 450 meters, S. lat. 70° 23′, Ludwig.
Pseudarchaster patagonicus (Per., 1891, p. K, 125, pl. XIII, figs. *2a, 2b,* as *Astrogonium*).
283 meters.

Hippasteria hyadesi Per.
326 meters.
Ceramaster patagonicus (Sladen).
55 to 245 fathoms.
C. austro-granularis (Per., 1891, as *Pentagonaster*).
340 meters.
Leptychaster kerguelenensis Smith.
Kerguelen and Marion Islands; 10 to 100 fathoms.
L. antarcticus Sladen.
210 fathoms.
Psilaster fleuriaisi (Per., 1891, as *Goniopecten*).
198 to 283 meters.
Cheiraster gerlachei Lud.
450 to 560 meters.
Pontaster planeta Sladen.
245 fathoms.
Ctenodiscus australis Lütk.
55 to 600 fathoms.
C. procurator Sladen.
40 to 1325 fathoms.

All the species (thirty-four) included in this list are generically allied to northern or arctic species. In many cases the resemblance is very close specifically. This is so especially in the cases of some species of *Henricia, Solaster, Pteraster, Diplopteraster, Porania, Hippasteria, Ceramaster,* and *Ctenodiscus.*

These facts clearly indicate that extensive migrations of the ancestors of these species have occurred, in the colder deep waters, in one or both directions, at no very remote geologic periods.

It appears, with our present knowledge of oceanic currents and temperatures, that the greater part of the migration would have been from the Arctic Ocean southward to the Antarctic. But no barriers exist, at the depths that these species inhabit, to prevent a northward migration, for abyssal species are not included in the list. The shallow-water and littoral species, on the other hand, show no evidence of such comparatively recent migrations, for much the larger part are peculiar to this region and the adjacent Antarctic seas and islands, with a few additions from the Indo-Pacific region.

Scarcely any of the strictly shallow-water species seem to have been able to cross the tropical regions, on either side of America, unless in remote geologic time.

Those that can descend to the depths where very cold water exists, even in tropical seas, have been able to migrate from polar seas across the tropics, probably in both directions, no doubt with extreme slowness, and yet with but little change in appearance or structure. Such

migrations have probably been going on during vast geologic periods and, no doubt, are still in progress.

Many of the existing genera of starfishes are doubtless of great antiquity, geologically speaking, and show wonderful persistence in many of the details of structure and habit.

X. LISTS OF EXTRALIMITAL SPECIES PARTIALLY DESCRIBED, REVISED, OR FIGURED.

Many other extralimital species, merely included in the faunal lists, or only mentioned by name under their genera, are not included in these lists.

I. NORTH ATLANTIC AND ARCTIC SPECIES.

Asterias vulgaris Ver.
New England.

Asterias forbesi Desor.
New England, etc.

A. acervata borealis = *A. polaris.*
Arctic and North Atlantic.

Orthasterias tanneri Ver.
Off East coast United States. Pl. XLVIII, fig. 6.

O. subangulosa Ver. (nom. nov.) = *A. angulosa* Per., preoccupied.
West Indies.

Stylasterias neglecta (Per. *non* Bell).

Coscinasterias tenuispina (Lam.) Ver.
Europe; Bermuda.

Marthasterias glacialis (Müll.) Jul.
Europe, etc.

Sclerasterias guernei Per.
East Atlantic.

Leptasterias littoralis (Stimp.) Ver.
New England.

L. compta (Stimp.) Ver.
New England.

L. tenera (Stimp.) Ver.
New England.

Ctenasterias spitzbergensis (D. and Kor.).
Arctic.

Urasterias linckii (M. and Tr.) Ver.
Nova Scotia; Arctic Ocean; post-glacial fossil at Salem, Mass. Pl. LXX, figs. 1-4.

U. panopla (Stuxb.) Ver.
Arctic.

Stichastrella rosea (Müll.) Ver.
Europe.

Coronaster briareus Ver.
West Atlantic.

Henricia sanguinolenta miliaris Ver.
New England.
H. antillarum (Per.).
West Indies.
H. sexradiata (Per.) Ver.
West Indies.
Crossaster korenii Ver. (nom. nov.).
Arctic and North Atlantic.
Asterina gibbosa (Penn.) Gray.
Europe.
A. pygmæa Ver. = *Porania.* (Young).
New England.
Asterinides folium (Lütk.) Ver.
West Indies; Bermuda.
Enoplopatiria marginata (Hupé) Ver.
West Indies; Brazil; West Africa, etc.
Tremaster mirabilis Ver.
Newfoundland Banks, etc.
Hippasteria phrygiana (Parel.) Ag.
New England; Europe; Arctic Ocean. Pl. XLVII, fig. 1; pl. XLVIII, figs. 1-5; pl. XLIX, fig. 6.
Mediaster bairdii Ver.
West Atlantic. Pl. II, fig. 2; pl. III, fig. 2 (type).
Blakiaster conicus Per.
West Indies.
Luidia clathrata (Say).
Southern coast United States; Bermuda; West Indies, etc. Pl. CIII, fig. 1.

2. PATAGONIAN, FUEGIAN, ANTARCTIC, AND SOUTH ATLANTIC SPECIES.

Labidiaster radiosus Lütk.
Pedicellaster antarcticus Lud.
Sporasterias rugispina (Stimp.) Per.
S. antarctica (Lütk.) Per.
S. perrieri (Smith).
S. rupicola (Ver.).
Anasterias minuta Per.
A. lysasteria (Ver.), nom. nov. = *A. perrieri* Std. (*non* Per.).
A. belgicæ Ludwig.
A. studeri (Perrier).
A. tenera Kœhler.
A. verrillii (Bell).
Pædasterias (gen. nov.) *chirophora* (Lud.) Ver.
Calvasterias asterinoides Per.
C. (*?*) *stolidota* Sladen.
Meyenaster gelatinosus (Meyen) Ver.
Smilasterias scalprifera Sladen.
Cosmasterias lurida (Phil.) Lud. Includes *C. sulcifera,* etc.
C. tomidata Sladen.
C. polygrammus (Sladen, as *Stichaster*).

C. brandti (Bell, as *Asterias*) Ver.
C. fernandensis (Meiss., as *Polyasterias*) Ver.
Gastraster studeri Kœhler.
Adelasterias (gen. nov.) *papillosa* (Kœhler, 1905, as *Asterias*).
Podasterias lütkeni Per.
P. meridionalis (Perrier, as *Asterias*).
P. spinosa (Perrier, as *Diplasterias*).
P. steineni Per.
Cryptasterias (gen. nov.) *turqueti* (Kœhler, as *Asterias*) Ver. Antarctic.
Granaster nutrix (Studer) Per. S. Georgia.
Hemiasterias biseriatus (Kœhler, as *Granaster*) Antarctic.
Stichaster striatus (M. and Tr.) = *Asterias aurantiaca* Meyen (*non* Linné). Peru and Chile.
Heliaster helianthus (Lam.) D. and H. Ecuador to Chile.
Henricia obesa (Sladen).
H. pagenstecheri (Studer).
H. hyadesi (Per.) Clark.
Cribraster sladeni Per.
Echinaster antonioënsis Kœhler.
E. (Rhopia) lepidus (Kœhler).
Poraniopsis echinaster Per.
P. mira (Kœhler, as *Lahillia*).
Acanthaster solaris (Schr.) D. and Hupé. Panamic, etc.
Patiria chilensis (Lütk.) Ver.
P. gayi (Per.) Ver.
Patiriella calcarata (Per.) Ver.
P. pusilla (Per.) Ver.
P. fimbriata (Per.) Ver.
P. bispinosa (Per.) Ver.
Asterinides perrieri (Kœhler, as *Asterina*) Ver.
Desmopatiria flexilis Ver.
Porania antarctica Smith.
Ganeria falklandica Gray.
G. papillosa Per.
Lebrunaster paxillosus Per.
Cycethra verrucosa (Phil.). Includes *C. simplex* Bell; *C. electilis* Sladen, etc.
C. lahillei Koehler.
Peribolaster foliculata Sladen.
Solaster australis (Per.)
Lophaster stellans Sladen.
Retaster gibber Sladen.
R. verrucosus Sladen.
Odontaster grayi (Bell).
O. penicillatus (Phil.). Includes *O. pilulatus* Sladen.
Asterodon singularis (M. and Tr.). Includes *O. granulosus* Per.
Leptychaster kerguelenensis Smith.
Luidia magellanica Leipoldt.
Astropectenides (gen. nov.) *mesacutus* (Sladen). South Atlantic.

3. SPECIES FROM THE PANAMIC FAUNA.

Coscinasterias alexandri (Ludwig, as *Stolasterias*).
Stylasterias robusta (Ludwig, as *Stolasterias*).
Acanthaster ellisii (Gray).
Mithrodia bradleyi Ver. Pl. CVIII, fig. 1 (type).
Enoplopatiria siderea Ver. Pl. CIX, fig. 4.
Echinaster tenuispinus Ver. Pl. CVII, fig. 2, type.
Asterinides modesta Ver.
Callopatiria obtusa (Gray) Ver.
Amphiaster insignis Ver. Pl. CVIII, fig. 1 (type).
Astropecten œrstedii Gray.
A. armatus Gray.

4. INDO-PACIFIC, AUSTRALIAN, AND JAPANESE SPECIES.

Labidastrella (gen. nov.) *annulata* (Sladen, as *Labidiaster*).
Australasian; off Heard Island and Kerguelen Island, in 75-150 fathoms.
Heterasterias (gen. nov.) *volsellata* (Sladen, as *Asterias*).
Japan.
Coscinasterias acutispina (Stimp.).
Japan.
C. muricata Ver.
New Zealand.
Allostichaster (gen. nov.) *polyplax* (M. and Tr.) Ver.
Australasian.
Distolasterias stichantha (Sladen) Ver.
Japan.
Allasterias forficulosa Ver.
Japan. Pl. LXXXIII, figs. 3-3*c*; pl. LXXXIV, fig. 1.
A. versicolor (Sladen) Ver.
Japan.
A. amurensis (Lütk.) Ver.
Siberia.
A. migrata (Sladen, 1878, as *Asteracanthion rubens* var.).
Straits of Korea.
Cœlasterias australis Ver.
New Zealand.
Acanthaster planci (Linné)=*A. echinites* of authors.
Indo-Pacific.
Henricides (gen. nov.) *heteractis* (Clark, as *Henricia*).
Lord Howe I.; Australasian.
Henricia densispina (Sladen, 1878).
Straits of Corea; 40 fathoms.
H. japonica Ver.
Japan.
Patiria coccinea Gray.
Indo-Pacific.
Asterinopsis penicillaris (Lam.) Ver.
Indo-Pacific; Australasian.
Patiriella regularis Ver.
New Zealand.

XI. LIST OF NEW GENERA ESTABLISHED AND DESCRIBED.

Brisingidæ:

Labidastrella. Type *Labidiaster annulata* Sladen.

Asteriidæ:

Evasterias. Type, *E. troschelii* (Stimpson).
Orthasterias. Type, *O. columbiana* Verrill.
Stylasterias. Type, *O. forreri* (de Loriol).
Heterasterias. Type, *H. volsellata* (Sladen).
Stenasterias. Type, *S. macropora* Ver.
Ctenasterias. Type, *C. spitzbergensis* (Danielssen and Koren).
Tosiaster. Type, *T. arcticus* Ver.
Allostichaster. Type, *A. polyplax* (Müller and Troschel).
Pædasterias. Type, *P. chirophora* (Ludwig).
Adelasterias. Type, *A. papillosa* (Kœhler).
Cryptasterias. Type, *C. turqueti* (Kœhler).
Parasterias. Type, *P. albertensis* Verrill.
Stichastrella. Type, *S. rosea* (Müller).
Hemiasterias. Type, *H. biseriatus* (Kœhler, as *Granaster*).

Echinasteridæ:

Henricides. Type, *H. heteractis* (Clark).

Astropectinidæ:

Astropectinides. Type, *A. mesacutus* (Sladen).

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